# HEADS OF LECTURES

ON A COURSE OF

## EXPERIMENTAL PHILOSOPHY,

PARTICULARLY INCLUDING

# CHEMISTRY,

DELIVERED AT THE NEW COLLEGE
IN HACKNEY.

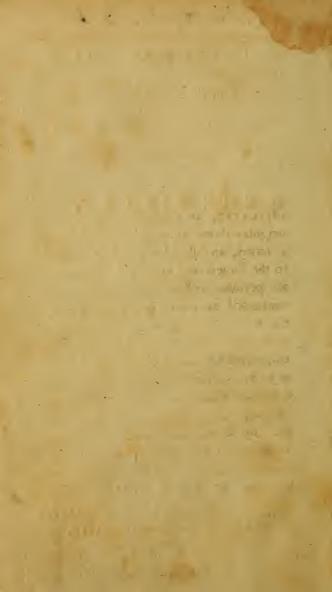*By JOSEPH PRIESTLEY LL.D. F. R. S.*

AC. IMP. PETROP. R. PARIS. HOLM. TAURIN. AUREL. MED. PARIS.
HARLEM. CANTAB. AMERIC. ET PHILAD. SOC.

QUI DOCET DISCIT.——WM. LILLY.

# THE PREFACE.

SITUATED, as I happily am, in the neighbourhood of the *New College at Hackney*, an inftitution that does honour to the Diffenters, an inftitution open to all perfons without diftinction *, and connected as I am by friendfhip with the tutors, I was glad to give it every affiftance in my power; and therefore undertook to read the *Lectures on Hiftory and General Policy* which I had compofed when I was tutor at Warrington, and alfo to give another courfe on the fubject of *Experimental Philofophy*. With this view I drew up the following *Heads of Lectures*; and, to fave the ftudents the trouble of tranfcribing

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* One gentleman of the Roman Catholic perfuafion, and feveral of the Church of England, are now in the College.

them,

them, they are now printed. To other
perfons they may ferve as a compendi-
ous view of the moft important difco-
veries relating to the fubject.

As it was found moft convenient, with
refpect to the other bufinefs of the col-
lege, to confine this courfe to one lecture
in a week, I contrived to bring within
that compafs as much of the fubject of
experimental philofophy as I well could,
and efpecially to include the whole of
what is called *chemiftry*, to which fo
much attention is now given, and which
prefents fo many new fields of philo-
fophical inveftigation.

Befides that the plan of the young
gentlemen's ftudies would not admit of
it, I think it moft advifable not to trou-
ble beginners with more than a large
outline of any branch of fcience.   By
this means they are not fatigued by too
long an attention to any one fubject, a
greater  variety  of  articles  may  be
brought before them, and in future life
they may purfue any of them as much
                              farther

farther as their inclination may difpofe, and their ability and opportunity fhall enable them to do it.

I do not give any acount of the *experiments* introduced into the feveral lectures. They will be fufficiently indicated by the fubjects of them. They were as many as I could conveniently make within the time; and where the experiments themfelves could not be made, I ufually exhibited both the different fubftances employed in them, and thofe that were the refult of them.

As thefe lectures were calculated for the ufe of the ftudents at the New College, I prefix an *Addrefs to them*, the fame in fubftance with that which I delivered to them at the clofe of the feffion of 1791. In it may be feen a fpecimen of the language we hold to them on the fubject of *politics*, which with reafonable men will ferve as an anfwer to the many calumnies that have been thrown out againft us, as difaffected to the government of this country.

A 3                Such

Such inftitutions will, indeed, always be objects of hatred and dread to *bigots* and the advocates for *arbitrary power*, but the pride of a truly *free country*. I therefore conclude with my earneft prayer (the accomplishment of which the prefent ftate of the College does not allow us to doubt) ESTO PERPETUA.

THE

# THE DEDICATION.

My young Friends,

Having drawn up the following *Heads
of Lectures* for your use, I take the liberty thus publickly to dedicate them
to you; and as I earnestly wish for your
improvement and happiness in all respects, excuse me if I take the farther
liberty of making a few observations,
and giving you some advice, of a more
general nature, adapted to your age and
circumstances.

As you will soon leave this place of
education, and enter upon your several
professions and employments, I hope
<center>A 4</center> your

your conduct will demonstrate to the world the solid advantages of this institution, and that the great expence attending it, and the best attention of the managers, have not been bestowed in vain.

Many liberal friends of science, of virtue, and of religion, have contributed to procure you the advantages which you enjoy. They have spared no pains to provide able and careful tutors, and you have had every other advantage for the profecution of your studies that they could procure you, unclogged by any subfcription to articles of faith, or obligation of any other kind, befides fuch as they have deemed neceffary for your own good, and to give the institution its greatest effect. This is an advantage you could not have found elfewhere, at least in this country. And in every feminary of education much more depends upon opportunity for study, free from any obstruction, and undue bias, than upon the ability of tutors; though there is an

additional

additional advantage when they are able men, and eminent in the branches of science which they undertake to teach. But this is by no means so essential as many other circumstances.

Whatever be the qualifications of your tutors, your improvement must chiefly depend upon yourselves. They cannot *think* or *labour* for you. They can only put you in the best way of thinking and labouring for yourselves. If, therefore, you get knowledge, you must acquire it by your own industry. You must form all conclusions, and all maxims, for yourselves, from premises and *data* collected, and considered by yourselves. And it is the great object of this institution to remove every bias the mind can lie under, and give the greatest scope to true freedom of thinking and enquiry. And provided you be intelligent and virtuous men, and good citizens, it will be no cause of regret to the friends of this institution, if, with respect to *religion*, or *politics*, you

A 5 adopt

adopt fyftems of principles, and maxims of conduct, very different from theirs.

Give me leave, now that I am ad-dreffing you as *young men*, and young *ftudents*, to fuggeft a caution on a fub-ject, of the importance of which it is hardly poffible that you fhould be fuffi-ciently aware, becaufe it is only impref-fed by that *experience* which you have not yet had. I mean that degree of va-nity which generally accompanies the acquirements that diligent perfons of your age make in places of liberal edu-cation, and the contempt they are too apt to entertain for thofe who have not made the fame proficiency with them-felves. And I affure you, that in the obfervations I fhall make on this fub-ject, I have no view whatever to any thing that I have obferved, or heard, of any of you in particular. But I have been in your fituation myfelf, and I know the importance of thefe obfer-vations to ftudents in general.

You

You are now at an age in which young perfons ufually make the moft fenfible advances in knowledge, and in which the underftanding appears to ripen in the moft rapid manner. You are able to fay every year, every month, and almoft every day, what particular advances you have made, and how much you know more than you did before. And being taught, and accuftomed, to exprefs your thoughts in writing, you find yourfelves qualified to do this in a manner of which you had no idea, or expectation, but a little time ago.—You alfo perfectly remember what you have fo recently learned. and in many refpects may be more particular and exact than even your tutors themfelves.

The almoft unavoidable effect of this is a high idea of your own powers and attainments, and too often a proportionable contempt of thofe who, not having had equal advantages, cannot do what you are eafily capable of. A certain degree of vanity is, therefore, excufable

excufable in young perfons; and, in-
deed, it is by means of it that they are
excited to exert themfelves in a manner
that they would not otherwife have done.
But be careful that this temper be not
ndulged to excefs, for it will then be
found to have ferious ill confequences;
the leaft of which is the precluding fu-
ture improvement, from being already
fatisfied with yourfelves, and confcious
of a fufficient fuperiority over others.

The foundation of this felf-conceit,
on account of literary attainments, will
be found to be extremely weak. In
fact, we learn more before the period
to which you are now arrived, and I
hope you will continue to learn more
after it, without its being fo much no-
ticed; and the *ability* that is difcovered
in the acquirements which are the fub-
jects of this vanity is not greater than
appears on other occafions. Only they
are not fo confpicuous.

What we all learn in the firft three
years of our lives, is much more extra-
ordinary

ordinary in its nature than all that we acquire afterwards. I mean the perfect use of our limbs, and the elements of speech. What we learn in a month in that early period of life, could not, if we were brought up in the ignorance of it, be learned in a year at any subsequent period. But these acquirements being universal, and what the circumstances in which we are all necessarily in compel us to learn, it does not appear extraordinary in any particular individual. Also, the proficiency that boys make at a grammar school, in which, in general, the dead languages only are taught (a knowledge of which is commonly the result of severe application) is too common to be the cause of much self conceit. But the advances that are made at places of liberal education are both less common, and of a more conspicuous nature.

You will also find, if you continue your application to study, that it is only the elements of science that you can acquire here, and if you live many years, they will bear but a small proportion to

your

your future acquirements. But thofe future acquirements, in confequence of their bearing a lefs proportion to your whole ftock of knowledge, will not be fo confpicuous. Thus, though all the buildings that in one year are added to fuch a city as London would make a pretty large country town, they bear fo fmall a proportion to what was built before, that they are not much noticed; whereas, had half the quantity of building been erected in a place where no houfe had exifted before, it would have been a memorable event in the hiftory of the country.

Alfo, as in old cities many buildings will fall to decay, while new ones are added; you muft expect to forget much of what you now know. No man can give equal attention to every object; and as we advance in life, we, in general, only learn new things at the expence of the old ones. But then they are the more valuable articles of knowledge, the more general and leading principles, which remain with us; while the more

<div align="right">ufelefs</div>

uſeleſs ones, things to which we give leſs attention becauſe we find them to be of leſs uſe, diſappear. Yet it is no uncommon thing for ingenious ſtudents to deſpiſe old ſcholars who are not ſo ready in the *minutiæ* of literature, though they may have forgotten more than thoſe youths ever knew, and may retain what they cannot acquire without forgetting as much.

Another obſervation proper to leſſen the conceit of literary men, is, that genius is not confined to *them,* but is equally great, though not equally conſpicuous, in every other line of life, and eſpecially in manufactures and the arts. Here, however, diſcoveries equal, with reſpect to *ſagacity,* to thoſe of Newton, contribute little to poſthumous fame, becauſe the diſcoverers are not writers.

But the greateſt branch of intellectual excellence, with reſpect to which every other is nothing, and which, from its nature, can never be a foundation of any ſelf conceit, is *virtue,* or right diſpoſitions

pofitions of mind, leading to right con-
duct in life. Proper fentiments, and juft
affections of mind, arife from juft, and
often comprehenfive, views of things,
paft, prefent and to come. And if the
real greatnefs of any thought, or action,
be eftimated by the number of elements
that conftitute it, and its remotenefs from
the dictates of fenfe and natural appetite,
a virtuous and pious man will appear to
be a much more dignified character,
more proper to be viewed with admira-
tion and efteem, than the greateft fcho-
lar; difcovering, in fact, greater com-
prehenfion and force of mind  I mean,
however, that virtue which is the refult
of reflection, of difcipline, and much
voluntary exertion, which, though
operating with equal promptnefs and fa-
cility, is as much fuperior to mere *inno-
cence*, and what is commonly called *good
nature*, as motions fecondarily automa-
tive are to thofe that are primarily fo;
a comparifon which you who have ftu-
died *Hartley's Theory of the Mind* will
fee the force of.

Thefe

These considerations I take the liberty to suggest, as being proper to lessen that vanity which is so incident to those who distinguish themselves in the fields of literature, and which, operating like the acquisition of riches, or power, or any possession that is *rare* among men, instead of enlarging, may tend to contract the mind, by confining its attention to itself. Beginning with a generous emulation, it proceeds to envy and jealousy, and ends in actual hatred and malignity, against which you cannot, surely, be too strongly put upon your guard; this being the greatest depravity to which human nature is subject, and which yet, like any other vice, may be in full possession of the mind, without the person himself knowing, or suspecting it; unless he give more attention to his feelings than most persons do. If no man ever thought himself to be avaricious, or cruel, can it be expected that any person should ever discover that he is too self-conceited?

Better,

Better, however, infinitely better, were it to rank with the mereſt dunces, than have the conceit and malignity (produced originally from conceit) of ſome who have diſtinguiſhed themſelves the moſt as linguiſts, critics, and poets. Even the ſtudy of nature, though, from its vaſt extent, it is leſs apt to produce this baneful effect, is not always a ſufficient guard againſt it. This is an affecting and an alarming conſideration. But in the intellectual, as in the civil and commercial world, we gain nothing but at the riſk of ſome loſs ; and in this caſe the poſſible gain is worth the riſk of even this great loſs.

For when literary and ſcientific excellence coincide with that which is of a moral nature, it adds unſpeakably to the value of a character. Ingenuity coupled with modeſty, and great genius with benevolence and true piety, conſtitute the perfection of human character, and is what we ſhould ever have in view. And a courſe of education in which both theſe objects are equally attended

t ended to, is the only one that deserves to be called *liberal:* but such as, I hope, you have found this to be.

Give me leave further to observe to you, that the time that you spend in a place of liberal education is of more importance to you than you can be at present aware of. Whatever be the sphere of life for which you are destined, the probability is, that you will hereafter have but little leisure for reading and studying, compared to what you have now. Besides, general maxims of all kinds, such as are the foundation of all our future conduct, in morals, religion, or politics, are generally formed at your time of life. From this period expect no great change in your opinions, or conduct; because now it is that you give particular attention to the forming your opinions on all subjects of importance; so that very little that is materially new to you can be expected to occur to you in future life, and almost every thing that you would choose to read will only tend to confirm you in the general principles

ciples that you will now adopt. There
are, no doubt, exceptions to this, as
well as every other general obfervation;
but it is wifdom to fuppofe, and to act
upon the fuppofition, that we are con-
ftituted as the generality of mankind
are, and that we fhall feel, and act, as
they do. Since then, fo much depends
on the leading principles and maxims
which you will now adopt, be it your
care to form juft and good ones, and let
no authority of tutors, or others, have
any undue influence over you. In all
cafes think and judge for yourfelves,
and efpecially on all fubjects of import-
ance, and with as much attention as
you can give to them.

It may not be amifs, in the prefent
ftate of things, to fay fomething re-
fpecting another fubject, which now
commands univerfal attention, You
cannot but be apprifed, that many
perfons entertain a prejudice againft this
College, on account of the republican,
and, as they choofe to call them, the
licentious, principles of government,

which

which are suppofed to be taught here.
Show, then, by your general converfa-
tion, and conduct, that you are the
friends of peace and good order; and
that, whatever may be your opinions
with refpect to the beft form of govern-
ment for people who have no previous
prejudices or habits, you will do every
thing in your power for the prefervation
of that form of it which the generality
of your countrymen approve, and un-
der which you live, which is all that can
be reafonably expected of any fubject.
As it is not neceffary that every good fon
fhould think his parent the wifeft and beft
man in the world, but it is thought fuf-
ficient if the fon pay due refpect and
obedience to his parent; fo neither is
it to be expected that every man fhould
be of opinion that the form of govern-
ment under which he happens to be born
is the beft of all poffible forms of go-
vernment. It is enough that he fubmit
to it, and that he make no attempt to
bring about any change, except by fair
reafoning, and endeavouring to convince
his countrymen, that it is in their power

to

to better their condition in that respect, as well as in any other. Think, therefore, speak, and write, with the greatest freedom on the subject of government, particular or general, as well as on any other that may come before you. It can only be avowed tyranny that would prevent this. But at the same time submit yourselves, and promote submission in others, to that form of government which you find to be most approved, in this country, which at present unquestionably is that by *King, Lords, and Commons.*

As to *religion*, we may, surely, be allowed to think and act entirely for ourselves; in all cases obeying God and conscience rather than man. But let us be thankful for the degree of liberty that we are allowed, though it be not all that we are justly entitled to ; and let us not use any other means than reason and argument in order to better our condition. By this peaceable and steady conduct we shall at length convince those who will hear reason, that we are enti-

<div align="right">tled</div>

tled to greater confideration; and doubt not but whatever is *true* and *right*, will finally prevail, and be univerfally eftablifhed.

That any of your tutors, or any of the friends of this inftitution, wifh to promote reformation, in church or ftate, by any other means than thofe of reafon, and argument, is a *calumny*, utterly void of foundation, or probability. But your conduct, difperfed as you will foon be in different parts of the country, will be the beft means of refuting it. Let us leave the method of proceeding by *riot* and *tumult* to thofe perfons to whofe fchemes fuch proceedings are congenial. Truth ftands in no need of fuch fupport, and will always triumph when affailed by fuch weapons. In return, then, for the advantages which you have enjoyed in this inftitution, do it this fervice; and in recommending it, I truft you are doing fubftantial fervice to the caufe of liberty and truth; and conferring a moft important benefit on your country, and on mankind.

# CONTENTS.

## LECTURE I.

## LECTURE XII.

## LECTURE XIII.

## LECTURE XIV.

## LECTURE XV.

## LECTURE XVI.

## LECTURE XVII.

## LECTURE XVIII.

LECTURE

## L E C T U R E   XIX.

## L E C T U R E   XX.

## L E C T U R E   XXI.

## L E C T U R E   XXII.

## L E C T U R E   XXIII.

# LECTURE XXIV.

# LECTURE XXV.

# LECTURE XXVI.

# LECTURE XXVII.

# LECTURE XXVIII.

                                       Of

## L E C T U R E   XXIX.

## L E C T U R E   XXX.

## L E C T U R E   XXXI.

## L E C T U R E   XXXII.

## L E C T U R E   XXXIII.

## L E C T U R E   XXXIV.

# LECTURE XXXV.

# LECTURE XXXVI.

# LECTURES

## ON

# EXPERIMENTAL PHILOSOPHY.

## LECTURE I.

### *The Introduction.*

THE object of experimental philofophy
is the knowledge of nature in general, or
more ftrictly, that of the properties of
natural fubftances, and of the changes of
thofe properties in different circumftan-
ces. This knowledge can only be at-
tained by *experiment*, or *obfervation* ; as
that clay is capable of becoming hard
by means of fire, and thereby being
made into bricks, and that by the fame
means limeftone can be converted into

B                        quick-

quick-lime, and by the addition of wa-
ter and fand, make mortar. It is by
obfervation alfo that we difcover that
ftones and other heavy bodies fall to the
ground, and that a magnet will attract
iron.    In other words, experimental
philofophy is an inveftigation of the wif-
dom of God in the works and the laws
of nature, fo that it is one of the great-
eft objects to the mind of man, and
opens a field of inquiry which has no
bounds; every advance we make fug-
gefting new doubts and fubjects of far-
ther inquiry.

The uniformity we difcover in the
properties of natural fubftances enables
us to lay down general rules, or princi-
ples, which, being invariable, we call
*the laws of nature*; and by our know-
ledge of thefe laws we are able to pre-
dict, and at our own pleafure to pro-
duce, particular refults, and this is the
fource of all the powers of man.   It is
the direction we acquire of the powers
of nature; fo that, as Lord Bacon obferv-
ed, *knowledge is power*.

All

All arts and manufactures are derived from fcience. Thus the doctrine of *mechanics* is an application of the law of gravitation. Every thing we are capable of doing by means of the fteam-engine is derived from our knowledge of the properties of water in fteam ; and all the great effects of gunpowder we owe to our knowledge of the compofition, and chemical properties, of that fubftance.

Every new appearance in nature is preceded by fome new circumftance, and to this, or rather to fomething always attending it, we fay that the appearance is *owing*. This circumftance we therefore call the *caufe*, and the new appearance the *effect* of that caufe. Thus we fay that the union of phlogifton to a particular kind of earth is the caufe of its becoming a metal.

It is one of the principal rules of philofophizing to admit no more caufes than are neceffary to account for the effects. Thus, if the power of gravity, by which

heavy

heavy bodies fall to the earth, be suffi-
cient to retain the planets in their orbits,
we are authorized to reject the *Cartesian
Vortices.* In other words, we must
make no more general propositions than
are necessary to comprehend all the par-
ticulars contained in them. Thus, after
having observed that iron consists of a
particular kind of earth united to phlo-
giston, and that it is soluble in acids;
and that the same is true of all other
metallic substances, we say, universally,
that all metals consist of a peculiar earth
and phlogiston, and that they are all so-
luble in some acid.

Of the circumstances which occasion
a change in the properties of bodies,
some are the addition of what are pro-
perly called *substances*, or things that are
the objects of our senses, being *visible,
tangible,* or having *weight,* &c. Thus
the addition of an acid changes an alkali
into a neutral salt. But other changes
are occasioned either by a change of tex-
ture in the substance itself, or the addi-
tion of something that is not the object
of

of any of our senses. Thus, a piece of steel becomes a magnet by the touch of another magnet, and a drop of glass acquires the property of flying asunder by a small fracture, in consequence of falling when red hot into cold water. Such also, in the opinion of some, is the difference between hot and cold substances.

Till the nature of the cause be ascertained, it is convenient to make use of the term *principle*, as including both of the above-mentioned causes of the change of properties in bodies. Thus, whatever be the real cause of gravity, or of inflammability, we may speak of the *principle of gravity*, or of *inflammability*; whether, with Newton, we suppose gravity to be occasioned by a fluid pervading the whole universe, which he termed *æther*, and whether inflammability be caused by the presence of a real substance called phlogiston, or not. In this manner we use the letters $x$ and $y$ to denote unknown quantities in algebra.

When changes are made in substances by the addition of other substances, they

make

make what is called a *chemical union*;
and in this cafe the properties of the
compound cannot with any certainty be
deduced from thofe of the component
parts, but muft be afcertained by frefh
experiments. Thus, from the fpecific
gravities, or the degrees of fufibility, of
two metals, thofe of the compound can-
not be predicted. Neither water nor
acid of vitriol will feparately diffolve
iron, fo as to produce inflammable air, but
both together will do it. However, the
properties of fimilar compounds are fimi-
lar to one another. Thus, all metals dif-
folved in acids are precipitated by mild
alkalis. This chemical union of two
fubftances we afcribe to a certain *elective
attraction*, or *affinity* that fubfifts be-
tween them, in confequence of which
they unite with one another whenever a
proper opportunity offers, in preference
to thofe fubftances to which they were
before united. Thus the vitriolic acid,
having a ftronger affinity with the veget-
able alkali which is the bafis of nitre,
will unite with that alkali, and with it
form another compound, called *vitri-*
                              *-olated*

*elated tartar*, while the acid of nitre, being detached from its bafe, is collected feparately.

When two fubftances compofe one liquid, and a third, which has a ftronger affinity with either of the two parts than they have with each other, is added to them, it will unite with that part, and take its place in the folution, while the other will in many cafes be precipitated, and may be collected. Thus the earth of alum is precipitated from a folution of alum by falt of tartar. This is the cafe of *fimple affinity*.

When both the fubftances are compounds, the component parts of which have a weaker affinity with each other than they have with thofe of the other compound, two new combinations are formed, and this is called a cafe of *double affinity*. Thus when phlogifticated alkali is poured into a folution of green vitriol, the acid of the vitriol unites with the alkali, while the phlogifton joining the calx of iron makes Pruffian blue.

All

All nature lying open to our investigation, we must consider the different parts in some order. But it is not very material which we adopt, because, begin where we will, the properties of the substances we first treat of will be connected with those which must be particularly considered afterwards, the changes in one substance being occasioned by its union with another. It will be impossible, for example, to explain the properties of metals without considering the *acids*, because by their union with acids very important changes are made in their properties.

There have been three principal methods of arranging natural substances. One is according to the *three kingdoms*, as they are called, into which they have been distributed, viz. the *mineral*, the *vegetable*, and the *animal*. Another is according to the *elements* which enter into their composition, and a third according to the *form* in which they are usually found, viz. *aerial*, *fluid*, or *solid*. Upon the whole this last appears to me

to

to be the mo convenient, efpecially as it is eafy to intermix general obfervations concerning the other divifions when they are particularly wanted. As there will be frequented occafion to fpeak of the component and elementary parts of all fubftances, I fhall here obferve, that, according to the lateft obfervations, the following appear to be the elements which compofe all natural fubftances, viz. *dephlogifticated air*, or the *acidifying principle*; *phlogifton*, or the *alkaline principle*; the different *earths*, and the principles of *heat*, *light*, and *electricity*. Befides thefe, there are the following principles which have not been proved to be fubftances, viz. *attraction*, *repulfion*, and *magnetifm*. By the help of thefe principles we are able, according to the prefent ftate of natural knowledge, to explain all the appearances that have yet occurred to us.

## LECTURE II.

*Of the Properties of all Matter.*

BEFORE I confider the properties of particular fubftances, it will be proper to mention thofe which are common to them all.    But I fhall firft obferve, that the term *fubftance* has no proper idea annexed to it, but is merely a convenience in fpeech; fince we cannot fpeak of the properties of fubftances, fuch as *hard*, *round*, *coloured*, &c. &c. (which circumftances alone affect our fenfes, and thereby give proper ideas) without faying that they inhere in, or belong to, fome *thing*, *fubftance*, or *fubftratum*. The terms *being* and *perfon* are alfo in the fame predicament.

One property of all fubftances is *extenfion*, fince they all occupy fome portion of fpace.

The

The incapacity of any fubftance to change its place has been termed, though improperly, the *vis inertiæ* of matter. It is fufficient to fay, that neither this, nor any other effect can be produced without a caufe.

*Infinite divifibility* is a neceffary property of all extended fubftance ; and from this circumftance it will follow, that the fmalleft quantity of folid matter may be made to fill the largeft fpace, and yet none of the pores fhall exceed the fmalleft given magnitude ; and confequently, that, for any thing we know to the contrary, all the bodies in the univerfe may be comprized in the fmalleft fpace.

Another property ufually afcribed to all matter is *impenetrability*, or the neceffary exclufion of any fubftance from the place occupied by another. But the only proof of impenetrability is the *refiftance* that we find to our endeavours to put one fubftance into the place of another ; and it is demonftrated by experiments,

ments, that this refiftance is not occafioned by the actual contact of the fubftances, but by a power of repulfion acting at a real diftance from their furfaces. It requires a confiderable force to bring two folid fubftances into as near contact as the particles of the fame fubftance; and that *thefe* are not in actual contact is evident, from their being capable of being brought nearer by cold; and this is moft remarkable with refpect to the heavieft, that is, the denfeft, of all fubftances, viz. the metals.

A more pofitive argument for the penetrability of matter is, that the particles of light, after entering the denfeft tranfparent fubftance, do not appear to meet with any obftruction to their progrefs till they come to the oppofite fide.

The powers of *attraction* and *repulfion* feem to be common to all matter, and the component parts of all fubftances are kept in their places by the due balance of thofe oppofite powers. If, by

by any means, the particles of any fub-
ftance be removed beyond their fphere
of mutual attraction, they repel one
another, as thofe of water when it be-
comes fteam.

Of the different kinds of attraction,
that of *gravitation* feems to extend to
the greateft poffible diftance ; but that
which keeps together the parts of the
fame fubftance, thence called the *at-
traction of cohefion*, and the different
kinds of chemical attractions, called *af-
finities*, only act at a fmall diftance. Of
the caufes of thefe attractions we are en-
tirely ignorant.

## Of *Aeriform Subftances.*

AERIFORM fubftances, of which the air that we breathe is one, though invifible, are real fubftances, as appears by their excluding other fubftances.

That the air has *weight* appears by actually weighing a veffel before and after it is exhaufted of air by means of an airpump (an inftrument contrived for that purpofe) by its burfting a bladder, and various other experiments.

Air, being a fluid, preffes in all directions, as in the experiment of the fountain in *vacuo,* and others.

The weight of the air is the caufe of the fufpenfion of mercury in a barometer, and of the action of pumps. The weight of atmofpherical air is to that of water in the proportion of about 1 to 800, fo as to prefs with the weight of about fourteen pounds on every fquare inch of furface.

Air, being an elaſtic fluid, is capable of occupying more or leſs ſpace according to the preſſure which it ſuſtains, as appears by a bladder partially filled with air being expanded when the air is drawn from a receiver in which it is put, by means of the air-pump, and compreſſed in the condenſing engine, an inſtrument the reverſe of the air-pump.

Air is neceſſary to the conveyance of ſound, to the exiſtence of flame, and to animal life.

LECTURE

## LECTURE III.

### Of Atmospherical Air

THE firſt ſpecies of air that offers itſelf to our conſideration is that of the atmoſphere, which appears to conſiſt of a mixture of two kinds of air, of different and oppoſite qualities, viz. dephlogiſticated and phlogiſticated, in the proportion of about one third of the former to two thirds of the latter. It is by means of the former of theſe two ingredients that it is capable of ſupporting flame and animal life.

This compoſition of atmoſpherical air is proved by ſeveral ſubſtances abſorbing the dephlogiſticated air, and leaving the phlogiſticated. All theſe proceſſes have been termed *phlogiſtic*, becauſe the effect is not produced but by ſubſtances ſuppoſed to contain phlogiſton

gifton in a volatile ftate; and by the affinity between phlogifton and the dephlogifticated part of the air, the one is feparated from the other. Of thefe procefſes are the calcination of metals, a mixture of iron-filings and fulphur, liver of fulphur, the burning of phof-phorus, and the effluvia of flowers.

In fome cafes, however, it is not fo clear that any thing is emitted from the fubftance that produces this effect; for water deprived of all air will abforb the dephlogifticated part of the atmofpherical in preference to the phlogifticated part.

As the purity of atmofpherical air, or its fitnefs for refpiration, depends upon the proportion of the dephlogifticated air that it contains, any of the abovementioned procefſes will fuffice to determine it. The more any given quantity of air is diminifhed by any of them, the purer it was before the diminution. But this effect is produced the moft quickly by a mixture of nitrous air, or firing

firing inflammable air in it, being almoſt
inſtantaneous.

In order to meaſure the purity of air,
it is convenient to take more of the ni-
trous or inflammable air than is neceſſa-
ry to ſaturate the dephlogiſticated air it
contains. Equal quantities of each beſt
anſwer the purpoſe. Suppoſing a given
quantity of atmoſpherical air to be mix-
ed with any equal quantity of nitrous air.
and the reſiduum to be 1. 1 meaſure,
the proportion of dephlogiſticated and
phlogiſticated air in it may be found by
the following arithmetical operation, it
being here taken for granted that one
meaſure of pure dephlogiſticated air will
ſaturate two meaſures of pure nitrous
air.

        2. 0 viz. one of each.
        1. 1 the reſiduum.
        ─────────
   3) 0. 9 the quantity that has diſap-
peared.
     0. 3 the dephlogiſticated air contained
             in the meaſure of the air exa-
             -mined.
And this ſubſtracted from 1. leaves .7 for
the proportion of phlogiſticated air in it.
                              LECTURE

# LECTURE IV.

## *Of Dephlogisticated Air.*

DEPHLOGISTICATED air, which is one
of the component parts of atmospheri-
cal air, is a principal element in the com-
position of acids, and may be extracted
by means of heat from many substances
which contain them, especially the ni-
trous and vitriolic; as from nitre, red
precipitate, the vitriols, and turbith mi-
neral, and also from these two acids
themselves, exposed to a red heat in an
earthen tube. This kind of air is also
contained in several substances which
had attracted it from the atmosphere, as
from precipitate *per se, minium,* &
*manganese.*

Dephlogisticated air is likewise pro-
duced by the action of light upon green
vegetables; and this seems to be the
chief means employed by nature to pre-
serve the purity of the atmosphere.

It

It is this ingredient in atmospheric air that enables it to support combustion and animal life. By means of it the most intense heat may be produced, and in the purest of it animals will live nearly five times as long as in an equal quantity of atmospherical air.

In respiration, part of this air, passing the membrane of the lungs, unites with the blood, and imparts to it its florid colour, while the remainder, uniting with phlogiston exhaled from the venous blood, forms fixed air. It is dephlogisticated air combined with water that enables fishes to live in it.

Dephlogisticated air is something heavier than atmospherical air, and the purity of it is measured by mixing with it two equal quantities of nitrous or inflammable air, deducting the residuum after the diminution from the three measures employed, and dividing the remainder by 3, as in the process for common air.

Of

## *Of Phlogisticated Air.*

THE other ingredient in the composition of atmospherical air is phlogisticated air. It is procured by extracting the dephlogisticated part of the common air, as by the calcination of metals, &c. &c. by dissolving animal substances in nitrous acid, and also by the union of phlogiston with nitrous air, as by heating iron in it, and by a mixture of iron-filings and sulphur.

Phlogisticated air extinguishes a candle, is entirely unfit for respiration, and is something lighter than common air. It is not capable of decomposition, except by exploding it together with a superabundance of dephlogisticated air, and a quantity of inflammable air, or by taking the electric spark repeatedly in a mixture of it and dephlogisticated air. In these cases nitrous acid is formed.

LECTURE

## L E C T U R E   V.

### Of Inflammable Air.

Inflammable air is procured from all combuſtible ſubſtances by means of heat and water, and from ſeveral of the metals, eſpecially iron, zinc, and tin, by the vitriolic and marine acids.

From oils and ſpirit of wine it is procured by the electric ſpark. By the ſame means alſo alkaline air is convert-ed into it.

That which is procured from metals, eſpecially by ſteam, is the pureſt and the lighteſt, about ten times lighter than common air; in conſequence of which, if a ſufficient quantity be con-fined in a light covering, it is poſſible to make it carry up heavy weights.

When it is procured from animal or vegetable ſubſtances, it is of a heavier

                                    kind,

kind, and burns with a lambent flame, of various colours, according to the circumftances.

Calces of metals heated in inflammable air are revived, and the air abforbed; and fince all the metals are revived in the fame inflammable air, the principle of metallization, or *phlogifton*, appears to be the fame in them all.

Pure inflammable air feems to confift of phlogifton and water, and the lambent kinds to be the fame thing, with the addition of fome oily vapour diffufed through it.

LECTURE

# LECTURE VI.

## Of Nitrous Air.

Nitrous air is procured by diffolving moft of the metals, efpecially iron, mercury, and copper, in the nitrous acid; but that from mercury feems to be the pureft. Nitrous air produced from copper contains a mixture of phlogifticated air. Some nitrous air is alfo obtained from the folution of all vegetable fubftances in nitrous acid; whereas animal fubftances in the fame procefs yield chiefly phlogifticated air: but in both thefe cafes there is a mixture of fixed air.

This fpecies of air is likewife produced by impregnating water with nitrous vapour. This procefs continues to have this effect after the water becomes blue, but ceafes when it turns green; there not then, probably, being a fufficient proportion of water. Nitrous

trous air is likewife produced by volatile alkali paffing over red hot manganefe, or green vitriol, when they are yielding dephlogifticated air  This fhews that dephlogifticated air is one ingredient in the compofition of nitrous air, and the fame thing appears by pyrophorus burning in it.  On the contrary, when nitrous air is made to pafs over red-hot iron, volatile alkali is produced.

Nitrous air is completely decompofed by a mixture of about half its bulk of dephlogifticated air, and the produce is nitrous acid.  And as nitrous acid is likewife formed by the union of inflammable and dephlogifticated air, one principal ingredient in nitrous air muft be common to it and inflammable air, or phlogifton.  This air is likewife decompofed by dephlogifticated nitrous acid, which by this means becomes phlogifticated.  It is alfo decompofed by a folution of green vitriol, which by this means becomes black, and when expofed to the air, or heated, emits nitrous air, and recovers its former colour.  Thefe decompofitions of nitrous

air

air feem to be effected by depriving it of phlogifton, and thereby reducing it to the phlogifticated air originally contained in it.

This kind of air is diminifhed to about one fourth of its bulk by a mixture of iron filings and brimftone, or by heating iron in it, or calcining other metals in it, when the remainder is phlogifticated air. All that iron gets in this procefs is an addition of weight, which appears to be water, but it lofes its phlogifton, fo that nitrous air feems to contain more phlogifton, and lefs water than phlogifticated air.

Nitrous air and dephlogifticated air will act upon one another through a bladder, but in this cafe there remains about one fourth of the bulk of nitrous air, and that is phlogifticated air; fo that in this cafe there feems to be a converfion of nitrous air into phlogifticated air without any addition of phlogifton.

Nitrous air is decompofed by pyrophorus, and by agitation in olive oil, which becomes coagulated by the procefs. It is alfo abforbed by fpirit of turpentine, by ether, by fpirit of wine, and alkaline liquors.

It is imbibed by charcoal, and both that air which is afterwards expelled from it by heat, and that which remains unabforbed, is phlogifticated.

Nitrous air refifts putrefaction, but is diminifhed by the animal fubftances expofed to it to about a fourth of its bulk, and becomes phlogifticated air. It is likewife fatal to plants, and particularly to infects.

When nitrous air is long expofed to iron, it is diminifhed and brought into a ftate in which a candle will burn in it, though no animal can breathe it. But this peculiar modification of nitrous air, called *dephlogifticated nitrous air*, is produced with the greateft certainty by diffolving iron in fpirit of nitre faturated

with

with copper, impregnating water with this air, and then expelling it from the water by heat. If bits of earthen ware be heated in this dephlogifticated nitrous air, a great proportion of it becomes permanent air, not mifcible with water, and nearly as pure as common air, fo that the principle of *heat* feems to be wanting to conftitute it permanent air.

LECTURE

# LECTURE VII.

## Of Fixed Air.

Having confidered the properties of thofe kinds of air which are not readily abforbed by water, and therefore may be confined by it, I proceed to thofe which *are* abforbed by it, and which require to be confined by mercury. There are two kinds, however, in a middle ftate between thefe, being abforbed by water, but not very readily; a confiderable time, or agitation, being neceffary for that purpofe. The firft of thefe is *fixed air*.

This kind of air is obtained in the pureft ftate by diffolving marble, limeftone, and other kinds of mild calcareous earth in any acid. It is alfo obtained by the burning, or the putrefaction, of both animal and vegetable fubftances, but with a mixture of both phlogifticated and inflammable air.

　　　　Fixed

Fixed air is alſo produced by heating together iron filings and red precipitate; the former of which would alone yield inflammable air, and the latter dephlo-giſticated. Fixed air is therefore a com-bination of theſe two kinds of air.

Another fact which proves the ſame thing is, that if charcoal of copper be heated in dephlogiſticated air, almoſt the whole of it will be converted into fixed air. On the ſame principle fixed air is produced when iron, and other inflammable ſubſtances, are burned in dephlogiſticated air; and alſo when mi-nium, and other ſubſtances containing dephlogiſticated air, are heated in in-flammable air.

That water is an eſſential part of fixed air is proved by an experiment upon *terra ponderoſa aerata*, which yields fixed air when it is diſſolved in an acid, but not by mere heat. If ſteam, however, be admitted to it in that ſtate, it will yield as much fixed air as when it is diſſolved in an acid.

Water

Water abforbs fomething more than its own bulk of fixed air, and then becomes a proper acid, Iron diffolved in this water makes it a proper chalybeate; as without iron it is of the fame nature with Pyrmont or Seltzer water, which by this means may be made artificially.

Ice will not imbibe this air, and therefore freezing expels it from water.

Fixed air extinguifhes flame, and is fatal to animals breathing in it. Alfo water impregnated with this air is fatal to fifhes, and highly injurious to plants. But water thus impregnated will prevent, in a great meafure, the putrefaction of animal fubftances.

Fixed air thrown into the inteftines, by way of glyfter, has been found to give relief in fome cafes of putrid difeafe.

## Of Hepatic Air.

ANOTHER species of air abforbed by water, but not inftantly, is termed *hepatic air*, being produced by the folution of liver of fulphur, or of fulphurated iron, in vitriolic or marine acid.

Water imbibes about twice its bulk of this kind of air, and it is then the fame thing with the fulphureous waters of Harrowgate.

## Of Phofphoric Air.

PHOSPHORIC air is produced by the folution of phofphorus in cauftic fixed alkali. If this air be confined by mercury, it will take fire on being admitted to atmofpheric, and much more to dephlogifticated air. After agitation in water it lofes this property, and the refiduum
is

is merely inflammable air, with no great diminution of its bulk. This kind of air, therefore, probably confifts of phof-phorus diffolved in inflammable air; though it cannot be made by melting it in inflammable air.

# LECTURE VIII.

*Of Dephlogisticated Marine Acid Air.*

THIS species of air is produced by heating spirit of salt with manganese; or more readily, by pouring acid of vitriol on a mixture of salt and manganese, in the proportion of about 16 of the former to 6 of the latter. In this case the acid of vitriol decomposes the salt, and the marine acid, disengaged in the form of air, takes dephlogisticated air from the maganese; so that this species of air seems to consist of marine acid vapour, and dephlogisticated air.

This species of air has a peculiarly pungent smell, and is absorbed by water as readily as fixed air.

The

The water takes about twice its bulk of it; and thereby acquires a yellowish tinge. Both this air, and the water impregnated with it, discharges vegetable colours from linen or cotton, and is thereby useful in bleaching.

This air when cold coagulates into a yellowish substance. It dissolves mercury, and with it forms *corrosive sublimate.*

## Of Phlogisticated Marine Acid Air.

BESIDES the preceding kinds of air which are slowly absorbed by water, there are others which are absorbed by it very rapidly, so that they cannot be confined but by mercury.

Of this kind is *phlogisticated marine acid air,* procured by the acid of vitriol and common salt; the former seizing upon the alkaline basis of the latter, and

and thereby expelling the marine acid
in the form of air.

It is called *phlogisticated* to distinguish
it from *dephlogisticated marine acid air*,
which seems to be the same thing, with
the addition of dephlogisticated air.

Phlogisticated marine acid air is hea-
vier than common air. It extinguishes
a candle with a blue flame. It dissolves
many substances containing phlogiston,
as iron, dry flesh, &c. and thereby
forms a little inflammable air. Water
absorbs 360 times its bulk of this air,
and is then the strongest spirit of salt.
It absorbs one-sixth more than its bulk
of alkaline air, and with it forms the
common sal ammoniac. Its affinity to
water enables it to dissolve ice, and to
deprive borax, nitre, and other saline
substances, of the water that enters into
their composition.

# LECTURE IX.

### Of *Vitriolic Acid Air.*

Vitriolic acid air is procured by heating in hot acid of vitriol almoſt any ſubſtance containing phlogiſton, eſpecially the metals which are ſoluble in that acid, as copper, mercury, &c. This kind of air is heavier than common air, and extinguiſhes a candle, but without any particular colour of its flame. It will not diſlodge the nitrous or marine acids from any ſubſtance containing them.

By its affinity to water it deprives borax of it.

One meaſure of this air ſaturates two of alkaline air, and with it forms the vitriolic ammoniac.

Water imbibes between 30 and 40 times its bulk of this air, and retains it when frozen. Water thus impregnated diſſolves ſome metals, and thereby yields inflammable air.

If

If this water be confined in a glafs tube, together with common air, and be expofed to a long continued heat, it forms real fulphur, the dephlogifticated part of the common air being imbibed, and forming real vitriolic acid, which uniting with the phlogifton in the air, forms the fulphur. Alfo this air mixed with atmofpheric air will, without heat, imbibe fome part of it, and thereby become the common acid of vitriol; fo that water impregnated with vitriolic acid air, commonly called *fulphureous*, or *phlogifticated acid of vitriol*, wants dephlogifticated air to make it the common acid of vitriol.

This kind of air is imbibed by oils, which thereby change their colour; whale oil becoming red, olive oil of an orange colour, and fpirit of turpentine of the colour of amber.

If this air be confined in a glafs tube by mercury, and the electric fpark be taken in it, a black tinge will be given to the glafs contiguous to the fpark, and this

this black substance appears to be mercury super-phlogisticated; since by exposure to air it becomes running mercury: so that the vapour of mercury must be diffused through every part of this air, to the distance of·at least several feet from the surface of the mercury.

## Of Fluor Acid Air.

FLUOR acid air is procured by dissolving the earthy substance called *fluor* in vitriolic acid.

This kind of air extinguishes a candle; and, like vitriolic acid air, one measure of it saturates two of alkaline air. It is peculiar to this kind of air to dissolve glass when it is hot.

It seems to consist of a peculiar acid vapour united to the stony substance of the fluor; for water being admitted to it absorbs the acid vapour, and the stony substance is deposited. By this means it exhibits an amusing appearance, whe-

ther

ther water be admitited to a glaſs jar pre-
viouſly filled with that air, or the bub-
bles of air be admitted, as they are
formed, to a quantity of water reſting
on mercury.

LECTURE

# LECTURE X.

## Of Alkaline Air.

ALKALINE air is produced by means of heat from cauftic volatile alkali, and alfo from a mixture of fal-ammoniac and flaked lime, in the proportion of about one-fourth of the former to three-fourths of the latter. In this cafe the marine acid in the fal-ammoniac unites with the calcareous earth, and the volatile alkali (probably with the affiftance of the water) takes the form of air.

This fpecies of air is heavier than inflammable air, but lighter than any of the acid airs. Like them, however, it diffolves ice, and deprives alum, and fome other faline fubftances, of the water which they contain. United with fixed air, it makes the concrete volatile alkali; with marine acid air, the common fal-ammoniac; and with water, the cauftic volatile alkali.

The

The electric spark, or a red heat, converts alkaline air into three times its bulk of inflammable air; and the calces of metals are revived in alkaline, as well as in inflammable air; but there remains about one-fourth of its bulk of phlogisticated air. These facts shew that alkaline air confists chiefly of phlogiston.

## Miscellaneous Observations relating to Air.

THE *nitrous* acid may be exhibited in the form of air, as well as the vitriolic, the marine, and the fluor acids. But it cannot be confined even by mercury, which it inftantly diffolves. It may, however, in fome meafure, be confined in a dry glafs veffel, from which it will in a great meafure expel the common air. This nitrous acid air is that red vapour, which is produced by the rapid folution of bifmuth, and fome other metals in the nitrous acid. But the vegetable acid cannot be exhibited in the form of air. It is only capable of being converted into vapour, like water: and in
the

the common temperature of our atmoſphere, returns to a ſtate of fluidity.

Different kinds of air which have no affinity to each other, when once mixed together will not ſeparate, notwithſtanding any difference of ſpecific gravity. Such is the caſe of a mixture of inflammable and dephlogiſticated air, and even of inflammable and fixed air. Without this property alſo, the phlogiſticated air, which conſtitutes the greateſt part of our atmoſphere, being ſpecifically lighter than dephlogiſticated air, of which the other part of it conſiſts, would ſeparate from it, and aſcend into the higher regions of the atmoſphere. Inflammable air, however, will not mix with acid or alkaline air.

Different kinds of air are expanded differently by the ſame degrees of heat; deplogiſticated air the leaſt, and alkaline air the moſt.

If any fluid, as water, ſpirit of wine, or even mercury, be heated in a porous
earthen

earthen veffel, furrounded by any kind
of air, the vapour of the fluid will
pafs through the veffel *one* way, while
the air paffes the *other*; and when
the operation ceafes, with refpect to
the *one*, it likewife ceafes with refpect
to the *other*.

LECTURE

# LECTURE XI.

*Of Liquid Substances;*

### AND FIRST OF

## *W A T E R,*

Having considered all the substances. that are usually found in the form of *air*, I come to those that are generally in a *fluid* form, beginning with *water*, which is the principal, if not the only cause of fluidity to all the other substances that I shall place in this class.

Pure water is a liquid substance, transparent, without colour, taste, or smell; and with different degrees of heat and cold may be made to assume the three forms of a solid, of a fluid, and of air. Below 32° of Fahrenheit it is ice, and above 212° it is vapour; so that in an atmosphere below 32° it never could have been

been known to be any thing elſe than a peculiar kind of ſtone, and above 212° a peculiar ſpecies of air.

In paſſing from the ſtate of a ſolid to that of a liquid, water abſorbs a great quantity of the principle, or matter, of *heat*, which remains in it in a *latent* ſtate; and in paſſing from a ſtate of fluid to that of vapour, it abſorbs much more; and this heat is found when the proceſſes are reverſed. It has been obſerved, that when water becomes vapour, it takes the form of ſmall globules, hollow within, ſo as to be ſpecifically lighter than air.

The degree of heat at which water is converted into vapour depends upon the preſſure of the atmoſphere; ſo that in vacuo, or on the top of a high moun-tain, it boils with little heat; and when compreſſed, as in Papin's digeſter, or in the bottom of a deep pit, it requires much heat. In the former caſe the re-ſtoring of the preſſure will inſtantly put a ſtop to the boiling, and in the lat-

ter

ter cafe the removing of the preffure will inftantly convert the heated water into vapour.

The eafe with which water is convert-ed into vapour by heat, has given a great power to mechanicians, either by employing the natural preffure of the atmofphere, when fteam is condenfed under a moveable piftern, in an iron cylinder, which was the principle of the old fire-engine, or by employing the elaftic power of fteam to produce the fame effect, which is the principle of Mr. Watt's fteam engine.

Water was long thought to be incom-preffible by any external force, but Mr. Canton has fhewn that even the preffure of the atmofphere will condenfe it very fenfibly.

We do not know any external force equal to that by which water is expand-ed when it is converted into ice, or into vapour. For though the particles of water approach nearer by cold, yet when it cryftallizes, the particles ar-

range

range themselves in a particular manner, with interstices between them; so that, on the whole, it takes up more room than before.

Water has an affinity to, and combines with, almost all natural substances, aerial, fluid or solid; but most intimately with acids, alkalies, calcareous earth, and that calx of iron which is called *finery cinder,* from which the strongest heat will not expel it.

It has been supposed by some, that by frequent distillation, and also by agitation, water may be converted into a kind of earth; but this does not appear to be the case. It has also of late been thought, that water is resolvable into dephlogisticated and inflammable air; but the experiments which have been alledged to prove this do not satisfy me; so that, for any thing that appeared till very lately, water might be considered as a simple element. By means of heat however, it seems to be resolvable into such air as that of which the atmosphere consists,

confifts, viz. dephlogifticated and phlo-
gifticated, only with a greater proportion
of the former.

Water with refpect to fpecific gravity
and temperature, has generally been
made the ftandard to all other fubftances;
its freezing and boiling points being the
limits by means of which thermometers
are graduated. Other fubftances have
alfo been compared with water, as a
ftandard, with refpect to the capacity of
receiving heat, and retaining it in a latent
ftate, as will be fhewn when we confider
the fubject of heat.

LECTURE

# L E C T U R E   XII.

## Of the Nitrous Acid.

U NDER the head of *liquids* I shall con-
sider *acids* and *alkalis*, though some of
them may be exhibited in the form of
air, and others in a solid form.   These
two chemical principles are formed to
unite with one another, and then they
constitute what is called a *neutral salt*.

Both acids and alkalis are distinguish-
able by their taste.   Another test, and
more accurate, is, that acids change
the blue juices of vegetables red, and
alkalis turn the syrup of violets green.

Acids are generally distinguished ac-
cording to the three kingdoms to which
they belong, viz. *mineral, vegetable,*
and *animal.* The mineral acids are
three, the *nitrous,* the *vitriolic,* and the
*marine.*

The

The nitrous acid is formed by the union of the pureſt inflammable air, or the pureſt nitrous air, with dephlogiſticated air. But it is uſually procured from nitre by means of the vitriolic acid, which, ſeizing its baſe, expels the nitrous acid in a liquid form. On this account this acid is ſaid to be weaker than the vitriolic.

If the nitrous acid be made to paſs through a red-hot earthen tube, it will be decompoſed, and the greateſt part of it be converted into dephlogiſticated air.

Like all other acids, the nitrous acid has a ſtrong affinity to water; but it is not capable of ſo much concentration as the vitriolic. It is generally of an orange or yellow colour; but heat will expel this colour in the form of a red vapour, which is the ſame acid in the form of air, and loaded with phlogiſton; and therefore when it is colourleſs it is ſaid to be dephlogiſticated. But the colourleſs vapour expoſed to heat, or to light, will become coloured again; and the liquid

acid

acid imbibing this coloured vapour, becomes coloured as before. This acid tinges the fkin of a yellow colour, which does not difappear till the epidermis be charged.

The nitrous acid unites with phlogifton, alkalis, metallic fubftances, and calcareous earth.

By means of its affinity with phlogifton it occafions that rapid accenfion called *detonation*, when any falt containing this acid, efpecially nitre, is applied to hot charcoal, or when charcoal is put to hot nitre. In fact the charcoal burns fo rapidly by means of the dephlogifticated air fupplied by the nitre.

A mixture of fulphur affifts the accenfion of thefe fubftances, and makes gunpowder, in the explofion of which much nitrous or phlogifticated air is fuddenly produced, and expanded by the heat. The application of this force, both to ufeful and deftructive purpofes, is well known. If, inftead of nitre, a

salt

falt made with dephlogifticated marine acid be made ufe of, the explofion is more eafily produced, and is much more violent. Friction will do this as well as heat.

Nitre alfo enters into the compofition of *pulvis fulminans*, viz. three parts nitre, two of dry alkali, and one of fulphur. This compofition melts, and yields a blue flame, before it explodes.

By means of the affinity of the nitrous acid to *oil*, another fubftance containing phlogifton, it is capable of producing not only a great heat, but even a fudden flame, efpecially when mixed with a little vitriolic acid.

Nitrous acid diffolves all metallic fubftances except gold and platina, and in the folution nitrous air is produced.

The particular kinds of faline fubftances formed by the union of the nitrous acid with the feveral metals and earths may be feen in tables conftructed for the purpofe. They are all deliquefcent.

LECTURE

# LECTURE XIII.

## *Of the Vitriolic Acid.*

THE vitriolic acid, fo called becaufe
it was originally procured from *vitriol*,
is now generally procured from fulphur;
the dephlogifticated part of the air uni-
ting with it in the act of burning.

That dephlogifticated air is effential
to this acid is evident from the decom-
pofition of it; for if the vapour of it
be made to pafs through a red-hot
earthen tube, a great quantity of de-
phlogifticated air is produced.

This acid has a ftrong affinity to
water, with which it unites with much
heat; and it is capable of greater con-
centration, or of being made fpecifically
heavier, than any other acid. When
pure, it is entirely free from colour and
         fmell,

fmell, owing, probably, to its being free from phlogifton, which is infeparable from the nitrous or marine acids.

The vitriolic acid will diflodge the nitrous, or marine, or any other acid, from their earthy or metallic bafes: from which property it is called the ftrongeft of all the acids.

By means of the fuperior affinity of the vitriolic acids to earths, and efpecially to *terra ponderofa*, the fmalleft quantity of it in water may be difcovered by a folution of this earth in the marine acid. In this acid the terra ponderofa is held in perfect folution; but with the vitriolic acid it forms a fubftance that is infoluble in water, and therefore it inftantly appears in the form of a white cloud.

Perhaps chiefly from the ftrong affinity which this acid has with water, *pyrophorus*, confifting of a mixture of alum and feveral fubftances containing phlogifton, takes fire fpontaneoufly on

expofure

expofure to the air. It is commonly made of three parts of alum and one of brown fugar, or of two parts alum, one of falt of tartar, and one of charcoal. They muft be heated till they have for fome time emitted a vapour that burns with a blue flame.

The faline fubftances produced by the union of this acid with the feveral earths and metals, are beft exhibited in tables conftructed for the purpofe. When united to three of the metals, viz. iron, copper, and zinc, they are called *vitriols*, green, blue, and white. And all the fubftances which this acid unites with cryftallize, and do not deliquefce.

This acid unites with oil, and the mixture is always black.

When any fubftance containing phlogifton is heated in the vitriolic acid, another fpecies of the acid, called *fulphureous*, is formed of a pungent fmell. In reality, it is water impregnated with vitriolic acid air. It makes, however,

a diftinct

a diftinct fpecies of acid, and is diflodged from its bafe by moft of the others.

## Of the Marine Acid.

THE marine acid is procured from common falt by the vitriolic acid, which unites with its bafe, the foffil alkali.

This acid is generally of a ftraw-co-lour; but this is owing to an impregnation with fome earthy matter, moft of which it readily diffolves, efpecially the metallic ones. It is lefs capable of concentration than the vitriolic or nitrous acids, perhaps from a more intimate union of phlogifton with it. No heat can extract from it any dephlogifticated air.

Though this is denominated a weaker acid than the nitrous, yet it will take filver, lead, or mercury, from their union with the nitrous acid. Upon this principle, a folution of thefe metals in the nitrous acid will readily difcover whether any water contains the marine

D 5                                    acid,

acid, the latter uniting with the metal diffolved in the former, and forming with it, if it be filver, a *luna cornea*; which being a fubftance infoluble in water, difcovers itfelf by a cloudy appearance.

The union of the marine acid with earths forms falts that eafily deliquefce, but with the metals fuch as are capable of cryftallization; and fo alfo is that formed by the union of this acid to terra ponderofa.

Neither this acid nor the nitrous will diffolve gold or platina; but a mixture of them, called *aqua regia*, will do it.

The marine acid has a ftrong affinity to dephlogifticated air, and will take it from manganefe and other fubftances; and with this union it becomes a different acid, called *dephlogifticated marine acid*, being water impregnated with dephlogifticated marine acid air, defcribed above.

LECTURE

# LECTURE XIV.

*Of the Vegetable Acids, and others of a less
perfect nature.*

THE principal of the vegetable acids
are the *acetous* and the *tartareous*. The
acetous acid is the produce of a peculiar
fermentation of vegetable substances,
succeeding the *vinous*, in which ardent
spirit it is procured, and succeeded by the
*putrefactive*, in which volatile alkali is
generated.

Thus wine is converted into vinegar.
Crude vinegar, however, contains some
ingredient from the vegetable substances
from which it was procured: but dis-
tillation separates them, and makes the
vinegar colourless; though some of the
acid is lost in the process.

The

The acetous acid is concentrated by froſt, which does not affect the proper acid, but only the water with which it is united. It may likewiſe be concentrated by being firſt combined with alkalis, earths, or metals, and then diſlodged by a ſtronger acid, or by mere heat. Thus the acetous acid, combined with vegetable alkali, forms a ſubſtance that is called the *foliated earth of tartar* ; and it may be expelled from it by the vitriolic acid. When combined with copper it makes *verdigris* ; and from this union heat alone will expel it in a concontrated ſtate. The acetous acid thus concentrated is called *radical vinegar*. Still, however, it is weaker than any of the preceding mineral acids.

Several vegetables, as lemons, ſorrel, and unripe fruit, contain acids, ready formed by nature, mixed with ſome of the eſſential oil of the plants, which gives them their peculiar flavours. All theſe acids have peculiar properties ; but it is not neceſſary to note them in this very general view of the ſubject, Like

vinegar,

vinegar, thefe acids may be concentrated by froft, and alfo by a combination with other fubftances, and then expelled by a ftronger acid.

The *acid of tartar* is very fimilar to that of vinegar. Tartar, from which it is procured, is a fubftance depofited on the infide of wine-cafks, though it is alfo found ready formed in feveral vegetables. It confifts of the vegetable alkali and this peculiar acid. When refined from its impurities, it is called *cryftals*, or *cream of tartar*. The acid is procured by mixing the tartar with chalk, or lime, which imbibes the fuperfluous acid, and this is expelled by the acid of vitriol. Or it may be procured by boiling the tartar with five or fix times its weight of water, and then putting the acid of vitriol to it. This unites with the vegetable alkali, and forms vitriolated tartar; and the pure acid of tartar may be procured in cryftals, by evaporation and filtration, equal in weight to half the cream of tartar. This

This acid of tartar is more soluble in water than the cream of tartar.

This acid, united to the mineral alkali, makes *Rochelle salt.*

Every kind of wood, when diftilled, or burned, yields a peculiar acid; and it is the vapour of this acid that is fo offenfive to the eyes in the fmoke of wood.

A peculiar acid is obtained from moft vegetable fubftances, efpecially the farinaceous ones, and from fugar, by diftillation with the nitrous acid. This feizes upon the fubftance with which the acid was united, and efpecially the phlogifton adhering to it, and then the peculiar *acid of fugar* cryftallizes. Thus with three parts of fugar, and thirty of nitrous acid, one part of the proper acid of fugar may be obtained. By the fame procefs an acid may be procured from camphor.

The

The *bark of oak*, and some other vegetable substances, especially nut-galls, contain a substance which has obtained the name of *the astringent principle*; the peculiar property of which is, that it precipitates solutions of iron in the form of a black powder, and in this manner *ink* is made. But by solution in water and evaporation, crystals, which are a proper *acid of galls*, may be obtained.

*Amber* is a hard semitransparent substance, chiefly found in Prussia, either dug out of the earth, or thrown up by the sea. It is chiefly remarkable for its electrical property; but by distillation in close vessels there sublimes from it a concreted acid, soluble in 24 times its weight of cold water. Amber seems to be of vegetable origin, and to consist of an oil united to this peculiar acid.

The acids I shall mention next are of a mineral origin; but being of a less perfect nature as acids, I shall only just note them here,

*Borax*

*Borax* is a fubftance chiefly found in a cryftallized ftate in fome lakes in the Eaft Indies. It confifts of the mineral alkali and a peculiar acid, which may be feparated, and exhibited in white flakes, by putting acid of vitriol to a folution of it in water. This acid has been called *fedative falt*, from its fup-pofed ufes in medicine. It is an acid that requires fifty times its weight of water to diffolve it.

Several other mineral fubftances, as *arfenic, molybdena, tungften,* and *wol-fram,* in confequence of being treated as the preceding vegetable ones, have been lately found to yield peculiar acids. They are alfo produced in a concrete ftate, and require a confidera-ble proportion of water to make them liquid; but as the water in which they are diffolved turns the juice of litmus red, and as they alfo unite with alkalis, they have all the neceffary characteriftics of acids.

LECTURE

# LECTURE XV.

## *Of the Phosphoric Acid.*

THE moft important acid of. *animal* origin, though it has lately been found in fome mineral fubftances, is the *phof-phoric.*

Phofphorus itfelf is a remarkable fub-ftance, much refembling fulphur, but much more inflammable. It has been procured chiefly, till of late, from urine, but now more generally from *bones,* by means of the vitriolic acid, which unites with the calcareous earth of which bones confift, and fets at li-berty the phofphoric acid, or the bafe of that acid, with which it was naturally combined. The acid thus procured, mixed with charcoal, and expofed to a ftrong heat, makes phofphorus.

This

This fubftance burns with a lambent flame in the common temperature of our atmofphere, but with a ftrong and vivid flame if it be expofed to the open air when moderately warm. In burning it unites with the dephlogifticated air of the atmofphere, and in this manner the pureft phofphoric acid is produced.

This acid is alfo procured in great purity by means of the nitrous or vitriolic acids, efpecially the former, which readily combines with the phlogifton of the phofphorus, and thus leaves the acid pure. In this procefs phlogifticated air is produced.

This acid is perfectly colourlefs, and when expofed to heat lofes all its water, and becomes a glaffy fubftance, not liable to be diffipated by fire, and readily uniting with earths.

United to the mineral alkali, it forms a neutral falt, lately introduced into medicine. United to the mineral and vegetable
ble

ble alkalis naturally contained in urine, it has obtained the name of *microcosmic salt*, frequently used as a flux for mineral substances with a blow-pipe.

Besides the phosphoric, there are other acids of an animal origin; as that of *milk*, that of *sugar of milk*, that of the *animal calculus*, and that of *fat*.

The acid of milk is the four whey contained in butter-milk, which, by a tedious chemical procefs, may be obtained pure from any foreign substance.

The fugar of milk is procured by evaporating the whey to dryness, then diffolving it in water, clarifying it with the whites of eggs, and evaporating it to the confistence of honey. In this state white cryftals of the acid of fugar of milk will be obtained.

By diftilling thefe cryftals with nitrous acid, other cryftals of the proper *acid of fugar of milk* will be obtained, fimilar to thofe of the acid of fugar.

If

If the human calculus be diftilled, it yields a volatile alkali, and fomething fublimes from it which has a fourifh tafte, and therefore called the *acid of the calculus*. It is probably fome modification of the phofphoric acid.

Animal fat yields an acid by diftillation, or by firft combining it with quicklime, and then feparating it by the vitriolic acid. Siliceous earth is corroded by this acid.

**LECTURE**

# LECTURE XVI.

## Of *Alkalis.*

THE clafs of fubftances that feems particularly formed by nature to unite with acids, and thereby form *neutral falts*, are the *alkalis.* They have all a peculiar acrid tafte, not eafily defined. They change the blue juices of vegetables green, or purple, and in common with acids have an affinity with water, fo as to be capable of being exhibited in a liquid form; though when this water is expelled by heat, fome of them will affume a folid form.

Alkalis are of two kinds; the *fixed,* which have no fmell, and the *volatile,* which have a pungent one.

The fixed alkalis are of *vegetable* or *mineral* origin. When in a folid form, they both melt with a moderate heat, and uniting with earthy fubftances, make *glafs.* With an intenfe heat they are volatilized.

Vegetable

Vegetable alkali is procured by burning plants, and lixiviating the ashes; a purer kind by the burning of tartar, hence called *salt of tartar*; but the purest of all is got by the deflagration of nitre; the charcoal uniting with the acid as it assumes the form of dephlogisticated air, and the alkali being left behind.

Mineral alkali is found in ashes of sea weed. It is likewise the basis of sea-salt; from which it is separated by several processes, but especially by the calx of lead, which has a stronger affinity with the marine acid with which it is found combined.

Alkalis united with fixed air are said to be *mild*, and when deprived of it *caustic*, from their readiness to unite with, and thereby *corrode*, vegetable and animal substances. To render them caustic, they are deprived of their fixed air by quick-lime; and in this state they unite with oils, and make *soap*.

Alkalis

Alkalis have a ftronger affinity with acids than metals have with them; fo that they will precipitate them from their folutions in acid menftruums.

The vegetable fixed alkali has a ftrong attraction to water, with which it will become faturated in the common ftate of our atmofphere, when it is faid to *deliquefce*; and having the appearance of *oil*, the falt of tartar is thus faid to become *oil of tartar per deliquium*. On the other hand, the mineral and foffil alkali, is apt to lofe its water in a dry atmofphere, and then it is faid to *efflorefce*. In this ftate it is often found on old walls.

Volatile alkali is procured by burning animal fubftances; in Egypt (from whence, as contained in *fal ammoniac*, we till of late imported it) from camel's dung; but now from bones, by diftillation. To the liquor thus procured they add vitriolic acid, or fubftances which contain it. This acid unites with the alkali, and commor

falt

falt being put to it, a double affinity takes place. The vitriolic acid uniting with the mineral alkali of the falt, makes *Glauber falt*, and the marine acid uniting with the volatile alkali, makes *fal ammoniac*. Slaked lime added to this, unites with the marine acid of the ammoniac, and fets loofe the volatile alkali in the form of *alkaline air*, which combining with water, makes the liquid caustic volatile alkali. If chalk (containing calcareous earth united with fixed air) be mixed with the fal ammoniac, heat will make the calcareous earth unite with the marine acid, while the fixed air of the chalk will unite with the volatile alkali, and affume a folid form, being the *fal volatile* of the apothecaries.

# LECTURE XVII.

## Of Liquid Inflammable Substances.

OF liquid inflammable substances the principal is *spirit of wine*, sometimes called *ardent spirit*, and, when highly rectified, *alcohol*. It is obtained from vegetable substances by their going through the vinous fermentation. It is considerably lighter than water, colourless, and transparent, has a peculiar smell and taste, and the property of inebriating.

Ardent spirit seems to consist of a peculiar combination of phlogiston and water; for when the vapour of it is made to pass through a red-hot earthen tube, it is resolved into water and inflammable air. It is highly inflammable, and burns without smoke, or leaving any residuum; and in the act of burning its phlogiston so unites with dephlogisticated air as to make fixed air.

E                    Ardent

Ardent fpirit mixes readily with water in all proportions, and with effential oils, and balfams or refins, which are the fame thing infpiffated.

By its affinity with effential oils, ardent fpirit extracts them from aromatic plants; and thefe liquors have obtained the name of *tinctures.*

When the tinctures are diftilled, the more volatile parts of the effential oils, which come over in diftillation, have acquired the name of *waters*; as *Lavender water*, *Rofemary water*, &c. and what remains in the ftill is called *extract* of the plant. If the tinctures be diluted with much water, the refinous part of the plant will be obtained pure, and feparated from the extractive part, which will remain diffolved in the water, while the refin feparates from it.

Spirit of wine will not diffolve the gummy parts of vegetables; and by this means the gummy fubftances may be feparated from their folutions in
water,

water, the spirit uniting with the water only. On the other hand, if resins be dissolved in spirit of wine, the affusion of water will separate them. By means of the affinity of spirit of wine with water, it will seize upon the water in which several salts are dissolved, and thus produce an instant crystallization of them.

Salt of tartar has a greater affinity to water than spirit of wine, and by extracting water from it, will assist in concentrating it; but the best method of rendering spirit of wine free from water is distillation, the ardent spirit rising before the water.

Spirit of wine mixed with the vitriolic and other mineral acids, renders them milder, and thereby more proper for certain medicinal uses. This is called *dulcifying* them.

Spirit of wine is a powerful antiseptic, and is therefore of use to preserve vegetable and animal substances from putrefaction.

Cf

## Of Æther.

IF fpirit of wine be diftilled with al-
moft any of the acids, the produce is
a liquor which has obtained the name
of *Æther*, from its extreme lightnefs
and volatility, being much lighter, and
more volatile, than any other fluid
that we are acquainted with. It is
highly inflammable, but the burning
of it is accompanied with fmoke, and
fome foot; and on this account it is
a medium between fpirit of wine and
oil, the acid having taken from the
fpirit of wine part of the water that
was effential to it, at the fame time
that it communicated fomething of its
acid peculiarly modified; fince æthers
have different properties according to
the acids by which they are made;
as the *vitriolic*, the *nitrous*, the *marine*,
and the *acetous*. No æther, however,
can be made from the marine acid
till it has been in fome meafure de-
phlogifticated; from which it may be
                                    inferred,

inferred, that dephlogisticated air is necessary to the composition of æther. Vitriolic æther is the most common, in consequence of the process by which it is made being the easiest.

Æther does not mix with water in all proportions, like spirit of wine, but ten parts of water will take up one of æther. It easily mixes with all oils.

It is something remarkable, that though æther will not dissolve gold, it will take from aqua regia the gold that has been previously dissolved in it.

By the quick evaporation of æther a considerable degree of cold may be procured; and on this principle it has sometimes been applied to relieve the head-ach and other pains.

## LECTURE   XVIII.

### *Of Oil.*

OIL  is a liquid inflammable fubftance,
of great tenacity, difpofed to pour in
a ftream rather than in drops.  It is
little, if at all, foluble in water.  It
burns with fmoke and foot, and leaves
a refiduum of a coaly fubftance.  It
confifts of acid and water combined
with  phlogifton.

All oil is the produce of the ve-
getable or animal kingdom, no proper
mineral fubftance containing any of
it.

By diftillation oil is in part decom-
pofed, and by this means the thicker
kinds of oil are rendered thinner and
more volatile, the acid, to which their
confiftence is chiefly owing, being loft
in the procefs.  By repeated diftilla-
tion

tion it is fuppofed that all oils may
be brought almoft to the ftate of
æther, and even of ardent fpirit.

Acids act powerfully upon oils, but
very differently, according to the na-
ture of each. Alkalis alfo combine
with oils, and the lefs thin and vo-
latile they are, the more eafily are
they foluble in alkalis. The union
of alkali and oil makes *foap*. All oil
diffolves fulphur, and with it makes
what is called a *balfam*. Oils alfo dif-
folve metallic fubftances, but moft fen-
fibly copper and lead. United with
the calx of lead, it is ufed in paint-
ing.

Oil not readily mixing with water,
it will diffufe itfelf over its furface,
and, notwithftanding its tenacity, it will
do this very rapidly, and to a great
extent; and then it has the extraordi-
nary effect of preventing the action of
the wind upon the water, fo as to
prevent the forming of waves. If a
quantity of oil and water be put into

E 4       a glafs

a glafs veffel and fwung, the furface of the water below the oil will be feen to change with refpect to the veffel, but not that of the oil. If fpirit of wine be put upon them, that will be at reft, and both the lower fluids in motion.

Vegetable oil is of two kinds, the *foft*, or *mild*, which has little or no tafte or fmell, and the *effential* oil, which is thin, and retains the fmell and tafte of the plant from which it was extracted.

Mild or fweet oil is expreffed from the graint or kernels of vegetables, and requires a confiderable degree of heat to convert it into vapour, in which ftate alone it is capable of being inflamed.

*Effential oil* is volatile in the heat of boiling water, and is generally obtained by means of diftillation from the moft odoriferous forts of plants ; but is fometimes found in their veficles, as in the rind of an orange. The ftrong tafte of this kind of oil arifes from the difengaged acid which abounds in it; and by this means

means it is soluble in spirit of wine, which sweet oil is not: but it loses much of this property by repeated distillations. By long exposure to the air it loses its more volatile parts, and thereby approaches to the nature of a resin. This volatile odoriferous principle has been called the *spiritus rector* of the plant.

The essential oils of different plants differ much in their specific gravity, and also in the manner by which they are affected by cold, some being heavier and others lighter than water, and some being more difficultly, and others more easily congealed. Though the differences with respect to *weight* and *consistency* in these oils is probably owing to the state of the acid that is combined with them, these two properties are wholly independent of each other; some essential oils being very thin and yet heavy, and others thick and yet light. Essential oils are used in perfumes, and also in medicine, acting powerfully on the nervous system.

Essential

Effential oils are very apt to be adul-
terated. If it be with fweet oil, it may
be difcovered by evaporation on white
paper, or by a folution in fpirit of wine,
which will not act upon the fweet oil.
If fpirit of wine be mixed with it, it
will be difcovered by a milky appearance
upon putting water to it, which uniting
with the fpirit, will leave the oil much
divided. If oil of turpentine, which is
the cheapeft of effential oils, be mixed
with any of the more valuable kinds, it
will be difcovered by evaporation; a
ftrong fmell of turpentine being left on
the paper, or cloth, upon which the
evaporation was made.

Animal oil like the vegetable, is of
two kinds; the firft *butter*, or *fat*, which
is eafily congealed, owing to the quantity
of acid that is intimately combined with
it. It refembles the fweet oil of veget-
ables in having no fmell or tafte. The
other kind of animal oil is extracted by
diftillation from the flefh, the tendons,
the bones, and horns, &c, of animals.
It differs effentially from the other kind
of

of animal oil, by containing an alkali inſtead of an acid. By repeated diſtillation it becomes highly attenuated and volatile; and in this ſtate it is called the *oil of Dippel*, the diſcoverer of it.

All oil expoſed to much heat is in part decompoſed, and acquires a diſagreeable ſmell; and in this ſtate it is ſaid to be *empyreumatic :* but this property is loſt by repeated diſtillations.

Beſides the vegetable and animal oils above deſcribed, there is a foſſil oil called *bitumen*, the ſeveral kinds of which differ much in colour and conſiſtence; the moſt liquid is called *petroleum*, from being found in the cavities of rocks, and the more ſolid kinds are *amber, jet, aſphaltum*, and *pit-coal*. When diſtilled, the principal component parts of all theſe ſubſtances are an oil and an acid. But all foſſil oil is probably of vegetable or animal origin, from maſſes of vegetables or animals long buried in the earth. Their differences from reſins and other oily matters are probably owing to *lime;* the

the combinations of mineral acids and oils fo nearly refembling bitumens, the principal difference being their infolubility in fpirit of wine.

That the moft folid of thefe, as amber, has been formerly in a liquid ftate, is evident, from infects and other fubftances being frequently found in them; and pit-coal has been often found with both the internal texture and external appearance of wood; fo that ftrata of pit-coal have probably been beds of peat in fome former ftate of the earth.

LECTURE

# LECTURE XIX.

## *Of Solid Subſtances.*

ALL ſolid ſubſtances are capable of
becoming fluid by heat, and moſt of
them may thereby be reduced into a ſtate
of vapour, or air; and in paſſing from
a fluid into a ſolid ſtate their component
parts aſſume a particular mode of ar-
rangement, called *cryſtallization,* which
differs according to the nature of the
ſubſtance; ſo that all ſolids, eſpecially
if they be ſuffered to concrete ſlowly,
may be called *cryſtals.*

Excluſive of *ſalts,* which have been
conſidered already, as formed by the
union of acids and alkalis, ſolids in ge-
neral have obtained the names of *earths,*
or *ſtones,* which differ only in their tex-
ture; and they are diſtinguiſhed into
thoſe that are *metallizable,* or thoſe that
are

are not; the form r being called *ores*, and the latter simply *earths*; the principal of which are the *calcareous, siliceous, argillaceous, magnesia, terra ponderosa,* and a few others which have been discovered lately, but have not been much examined.

### Of Calcareous Earth.

CALCAREOUS earth is found in the shells of fishes, the bones of animals; chalk, limestone, marble, and gypsum: but all calcareous earth is supposed to be of animal origin; and beds of chalk, lime-stone, or marble, are thought to have been beds of shells formed in the sea, in some pristine state of the earth.

The calcareous earth which is found in shells, lime-stone, and marble, is combined with fixed air, discovered by effervescing with acids. To obtain it perfectly pure, the earth must be pounded and washed with water, in order to free it from any saline substance which

may

may be contained in it, then diffolved in diftilled vinegar, and precipitated by mild alkalis. Lime-ftone expofed to heat lofes about half its weight, in fixed air and water, and the remainder, called *quick-lime*, attracts water very powerfully, and their union is attended with much heat, after which it diffolves into a fine powder called *flaked lime*. If it be left expofed to the atmofphere, it will of itfelf, by gradually imbibing moifture, fall into the ftate of powder.

Water diffolves about one feven hundredth part of its weight of quick-lime, and is then called *lime-water*. Expofed to the air, a cruft will be formed on its furface, which is found to confift of calcareous earth and fixed air.

Lime and water mixed with fand make *mortar*, by which means different ftones may be made to cohere as one mafs, which is the moft valuable ufe of this kind of earth.

Calcareous

Calcareous earth, united with vitrio-lic acid, makes *gypfum*; and this fub-ftance pounded and expofed to heat, parts with its water, and is then called *plaifter of Paris*. In this ftate, by im-bibing water again, it becomes a firm fubftance, and thus is ufeful in making moulds, &c.

The earth of animal bones is calca-reous united to the phofphoric acid.

## Of Siliceous Earth.

SILICEOUS earth feems to be formed by nature from chalk, perhaps by the introduction of fome unknown acid, which the vitriolic acid is not able to dif-lodge. It abounds in moft fubftances which are hard enough to ftrike fire with fteel, as *flint*, *rock cryftal*, and moft *precious ftones*. It is not acted upon by any acid exeept the fluor and phofphoric, but efpecially the former; but it is folu-ble in alkalis; and being then diffolved in water, makes *liquor filicum*, from
which

which the pureſt ſiliceous earth may be precipitated by acids. For this purpoſe about four times the weight of alkali muſt be made uſe of. With about equal weights of alkali and ſiliceous ſand is made *glaſs*, of ſo great uſe in admitting light and excluding the weather from our houſes, as well as for making various uſeful utenſils. To make glaſs perfectly colourleſs, and at the ſame time more denſe, commonly called *flint glaſs*, manufacturers uſe a certain proportion of calx of lead and manganeſe.

Siliceous earth is not affected by the ſtrongeſt heat, except by means of a burning lens, or dephlogiſticated air.

LECTURE

## LECTURE XX.

### Of *Argillaceous Earth.*

Argillaceous earth is found in *clay,*
*fchiftus* or *flate,* and in *mica*; but the
pureft is that which is precipitated from
a folution of alum by alkalies; for alum
confifts of the union of vitriolic acid and
argillaceous earth.

This fpecies of earth is ductile with
water; it then hardens and contracts by
heat, fo as to be of the greateft ufe in
forming *bricks,* or ftones of any requir-
ed form or fize.  By means of the pro-
perty of clay to contract in the fire,
Mr. Wedgwood has conftructed an ex-
cellent thermometer to meafure the de-
grees of extreme heat.

The

The ductility of clay seems to depend upon some acid, probably the vitriolic, adhering to it; for it loses that property when it is burned into a brick, but recovers it when it has been again dissolved in an acid.

### Of Terra Ponderosa.

Terra Ponderosa, or *marmor metallicum*, is generally found in two states, viz. united to vitriolic acid, when it is called *calk*, or to fixed air, when it is called *terra ponderosa aerata*.

To obtain it pure from its union with the vitriolic acid, it must be melted with about twice its weight of fixed alkali; which unites with the acid, and forming a saline substance, may be washed out of it. In this state it contains water, and therefore, when exposed to heat, will yield fixed air; whereas the terra ponderosa aerata will not yield fixed air by heat only, but when steam

is

is made to pass over it when red hot.
This proves that water is essential to the
composition of fixed air.

This stone is distinguishable by its
great specific gravity, being four times
as heavy as water; but though in this it
resembles an *ore*, it has not been found
to be metallizable.

## Of *Magnesia*.

THIS species of earth is found in *stea-
tites*, or *soap rock*, *Spanish chalk*, *asbes-
tus*, and *Muscovy talck*; but the purest
is got by dissolving *Epsom salt* (which
consists of this earth united to the vitri-
olic acid) and precipitating it by a mild
alkali. In this state it becomes united
to fixed air, which may be expelled by
heat. It is then *calcined*, or *caustic*,
but differs from quick-lime by not being
soluble in water.

*Asbestus,*

*Afbeftus,* which contains much of this kind of earth, is remarkable for not being deftructible by heat, though it is fometimes found in flexible fibres, fo as to be capable of being woven into cloth.

*Mufcovy talck,* is remarkable for the thin and tranfparent flakes into which it is divifible, and thereby capable of various ufes.

There are fome other diftinct fpecies of earth, particularly one brought from Botany Bay, and another called *Stontiate,* from the place where it was found in Scotland; but they have not as yet been much examined.

All ftones formed by nature are compounded, and to diftinguifh them from one another, and afcertain the parts of which they confift, is the fubject of *lithology,* a very extenfive branch of knowledge.

All

All the simple earths are nearly, if not absolutely, *infusible*; but when they are mixed they may all be fused.

LECTURE

# LECTURE XXI.

## Of Ores.

METALLIZABLE earths, commonly called *ores*, when united to phlogiston, make the metals, distinguishable for their specific gravity, their opacity, shining appearance, and fusibility.

All the proper metals are *malleable*, and those which are not so are called *semi-metals*.

The metals again are subdivided into the *perfect* and *imperfect*. The former, which are *gold*, *silver*, and *platina*, suffer no change by fusion, or the longest continued heat: whereas heat calcines or dissipates the phlogiston of the imperfect metals, which are *mercury*, *lead*, *copper*, *iron*, and *tin*, so that they re-
turn

turn to the ſtate of earth; and this earth is always heavier than the metal, though of leſs ſpecific gravity, having received an addition of weight from water or air: but theſe earths, or ores, being expoſed to heat in contact with ſubſtances containing phlogiſton, again become metals, and are then ſaid to be *revived.*

The ſemi-metals are *biſmuth, zinc, nickel,* regulus of *arſenic,* of *cobalt,* of *antimony,* of *manganeſe,* of *wolfram,* and of *molybdena.*

All metallic ſubſtances are cryſtallizable, and each in a peculiar form, which is diſcovered by leaving a hole in the bottom of the crucible in which they are melted, and drawing out the ſtopper, when the maſs is beginning to loſe its fluidity.

Some of the metals will not unite to others when hot, and others of them will; and ſuch as will unite with others

are

are called *folders*. Thus tin is a folder for lead, and brafs, gold, or filver, for iron.

Ores are never found in regular ftrata, like the different kinds of earth; but in places which have formerly been cavities, running in all directions, with refpect to regular ftrata, and commonly called *veins*.

Many of the ores in their natural ftate are faid to be *mineralized* with arfenic or fulphur, thofe fubftances being intimately united with the metallic earths.

In order to convert the ores into metals, fome of them are firft reduced to powder, to wafh out the earthy or faline particles. They are then kept in a red heat, which the workmen call *roafting*, in order to drive away the arfenic, or fulphur, which are volatile; and in the laft place they are fufed in contact with charcoal, or other fubftances containing phlogifton; and to pro-

F                                    mote

mote the fufion, lime-ftone is frequently mixed with them. When the operation is completed, the unmetallic parts are converted into glafs, or *fcoria*, which lies on the furface, whereas the metal is found at the bottom.

To difcover the quantity of metal in a fmall piece of ore is called *affaying*.

When metals are fufed together, the fpecific gravity, fufibility, and other properties are changed, and in fuch a manner as could not be difcovered from the properties of the conftituent parts.

## *Of Gold.*

GOLD is the heavieft of all metallic bodies except platina. It appears yellow or reddifh by reflected light, but green or blue by tranfmitted light, when it is reduced to thin plates.

Though

Though gold undergoes no change in a common furnace, or burning lens, it may, in part, at least, be calcined by the electric shock.

Gold has the greatest *ductility*, and in wires of equal diameters, it has the greatest *tenacity*, of all the metals. One grain of it may be made to cover 56 square inches; some gold leaf being less than a 200,000th part of an inch thick; and when it is made to cover a silver wire, the gold upon it may not be more than one twelfth part of the thickness of the gold leaf.

This metal is soluble in aqua regia; and being precipitated by a volatile alkali, makes a powder called *aurum fulminans*, which is one fourth heavier than the gold, and explodes with great violence in a heat something greater than that of boiling water.

Tin precipitates gold in the form of a purple powder, called the *powder of*

*Cassius,*

*Caffius*, from the inventor of it, and is used in enamels, or the glaffy coating which is given to metals by heat.

Gold unites with moft of the metals, efpecially with mercury, and thefe mixtures are called *amalgams*. In gilding, the amalgam is applied to the furface of the metal to be gilded, and the mercury is driven off by heat, leaving the gold attached to the furface.

Gold mixed with iron, makes it harder, for the purpofe of cutting inftruments.

To feparate gold from the imperfect metals, fuch as copper, &c. it is mixed with lead, and then expofed to a ftrong heat, which calcines the lead, and with it the imperfect metals, leaving the gold pure. This procefs is called *cupellation*, from being performed in a fmall crucible called a *cupell*. When the gold is mixed with filver, three parts more of filver are put to it, and then the

the filver is diffolved by nitrous acid, leaving the gold pure. This procefs is called *quartation*, from the gold being one fourth part of the mafs.

The finenefs of gold is generally efti-mated by dividing the gold into twenty-four parts, called *carats*. The phrafe *twenty-three carats fine* means that the mafs contains twenty-three parts out of twenty-four of pure gold, the remain-der being *alloy*, of fome bafer metal. The finenefs of gold may in fome mea-sure be difcovered by the colour it leaves upon a *touch-ftone*, or fine-grain-ed bafaltes.

Gold is generally found nearly pure, but mixed with earth, or diffufed in fine grains through ftones.

# LECTURE XXII.

## Of Silver.

SILVER is the whiteſt of all the metals, very du&ile, but leſs ſo than gold; the thinneſt leaves of it being one third thicker than thoſe of gold. It is not calcined in the heat of a common fur-nace, but partially ſo by repeated fuſion, or a ſtrong burning lens.

Sulphureous fumes unite with ſilver, and tinge it black. The nitrous acid diſſolves it, and will hold more than half its weight of it in ſolution. When fully ſaturated, this ſolution depoſits cryſtals, which are called *lunar nitre*, or *nitre of ſilver*. When theſe cryſtals are melted, and the water they contain driven off, a black ſubſtance, called *lapis infernalis*, or *lunar cauſtic*, is formed. This is uſed

as

as a cautery in furgery. A ftrong heat will decompofe this lunar nitre, and re- cover the filver.

Though the nitrous acid diffolves filver the moft readily, the marine acid will deprive the nitrous of it, and form a fubftance called *luna cornea*, becaufe, when it is melted and cold, it becomes a tranfparent mafs fomething refembling *horn*. From this luna cornea the pureft filver may be obtained. The vitriolic acid will likewife deprive the nitrous of the filver contained in it, and form a white powder, not eafily foluble in water.

A fulminating filver may be made by the following procefs: the filver muft firft be diffolved in pale nitrous acid, then precipitated by lime-water, dried, and expofed to the air three days. It muft then be wafhed in cauftic volatile alkali, after which the fluid muft be decanted, and the black powder left to dry in the air. The flighteft friction will caufe this powder to fulminate. It

is

is faid, that even a drop of water falling upon it will produce this effect; fo that it ought to be made only in very fmall quantities, and managed with the greateft caution.

Moft of the metals precipitate filver. That by mercury may be made to affume the form of a tree, called *arbor Dianæ*.

Silver is found native in Peru; and the ores frequently contain fulphur, or arfenic, or both.

## Of Platina.

PLATINA is a metal lately difcovered in the gold mines of Mexico, where it is found in fmall particles, never exceeding the fize of a pea, mixed with ferruginous fand and quartz.

The ftrongeft fire will not melt thefe grains, though it will make them cohere; but they may be melted by a burning lens, or a blow-pipe fupplied with dephlogifticated air.

Pure

Pure platina is the heavieſt body in nature, its ſpecific gravity exceeding twenty-two. It is very malleable, though conſiderably harder than gold or ſilver, and has the property of welding in common with iron. This metal is not affected by expoſure to the air, or by any ſimple acid, though concentrated and hot; but it is diſſolved by dephlogiſticated marine acid, and by aqua regia, in which a little nitrous air is procured. The ſolution is brown, and when diluted yellow. This liquor is very corroſive, and tinges animal ſubſtances of a blackiſh brown colour. Platina is precipitated from a ſolution in aqua regia by ſal-ammoniac, as gold is by martial vitriol. Iron is precipitated from this ſolution by the Pruſſian alkali. Alſo moſt of the metals precipitate platina, but not in its metallic ſtate.

Arſenic facilities the ſolutaton of platina; and by melting it with equal parts of arſenic and vegetable alkali, and then reducing the maſs to a powder, it may be made to take any form; and a

ſtrong heat will diſſipate the arſenic and the alkali, leaving the platina in the ſhape required, not fuſible by any heat in a common furnace.

Platina does not readily combine with gold or ſilver, and it reſiſts the action of mercury as much as iron; but it mixes well with lead, making it leſs ductile, and even brittle, according to the proportion of the platina. With copper it forms a compound which takes a beautiful poliſh, not liable to tarniſh, and is therefore uſed with advantage for mirrors of reflecting teleſcopes. It unites eaſily with tin, and alſo with biſmuth, antimony, and zinc.

LECTURE

# LECTURE XXIII.

## Of Mercury.

Mercury is the most fusible of all the metals, not becoming solid but in 40° below o in Fahrenheit's thermometer. It is then malleable. It is heavier than any other metal except gold or platina. It is volatile in a temperature much lower than that of boiling water, and in vacuo in the common temperature of the atmosphere; and at six hundred it boils.

In a degree of heat in which it would rise easily in vapour, mercury imbibes pure air, and becomes a red calx, called *precipitate per se*. At a greater degree of heat it parts with that air, and is running mercury again.

Mercury is not perceptibly altered by exposure to the air.

Mercury is acted upon by the vitriolic acid when hot. In this procefs vitriolic acid air is procured, and the mercury is converted into a white fubftance, which being dipped in water becomes yellow, called *turbith mineral*, one third heavier than the mercury from which it was made. By heat this fubftance parts with its pure air, and becomes running mercury; but if the procefs be made in a clean earthen veffel, there will remain a portion of *red calx*, which cannot be reduced by any degree of heat, except in contact with fome fubftance containing phlogifton. If this be done with a burning lens, in inflammable air, much of the air will be abforbed.

Mercury is diffolved moft readily in the nitrous acid, when the pureft nitrous air is procured; and there remains a fubftance which is firft yellow, and by continuance red, called *red precipitate*. In a greater degree of heat the dephlogifticated air will be

recovered,

recovered, and the mercury be re-
vived; but the fubftance yields nitrous
air after it becomes folid, and till it
changes from yellow to red.

The precipitates of mercury from
acids by means of alkalis poffefs the
property of exploding, when they are
expofed to a gradual heat in an iron
fpoon, after having been triturated
with one fixth of their weight of the
flowers of fulphur. The refiduum con-
fifts of a violet-coloured powder, which,
by fublimation, is converted into cin-
nabar.

It feems, therefore, as if the fulphur
combined fuddenly with the mercury,
and expelled the dephlogifticated air in
an elaftic ftate.

The marine acid feizes upon mer-
cury diffolved in nitrous acid, and if
the acid be dephlogifticated, the pre-
cipitate is *corrofive fublimate*; but with
common marine acid, it is called *ca-
lomel*, or *mercurius dulcis*. This pre-
<div align="right">paration</div>

paration is generally made in the dry way, by triturating equal parts of mercury, common falt and vitriol, and expofing the whole to a moderate heat; when the corrofive fublimate rifes, and adheres to the upper part of the glafs veffel in which the procefs is made.

Mercury combines readily with fulphur by trituration, and with it forms a black powder called *Ethiops mineral.* A more intimate combination of mercury and fulphur is made by means of fire. This is called *cinnabar,* about one third of which is fulphur. Vermillion is cinnabar reduced to powder.

Mercury readily unites with oil, and with it forms a deep black or blue compound, ufed in medicine.

It readily combines with moft of the metals, and when it is ufed in a fufficient quantity to make them foft, the mixture is called an *amalgam.* It combines moft readily with gold, fil-

ver,

ver, lead, tin, bifmuth, and zinc. Looking-glaffes are covered on the back with an amalgam of mercury and tin.

When mercury is united with lead or other metals, it is rendered lefs brilliant and lefs fluid; but agitation in pure air converts the impure metal into a calx, together with much of the mercury, in the form of a black powder.

Heat recovers the pure air, and the mercury, leaving the calx of the impure metal.

Much mercury is found native in a flaty kind of earth, or in maffes of clay or ftone; but the greateft quantity is found combined with fulphur in *native cinnabar*.

LECTURE

# LECTURE XXIV.

## Of Lead.

LEAD is a metal of a bluish tinge, of no great tenacity, but very considerable specific gravity, being heavier than silver. It melts long before it is red hot, and is then calcined, if it be in contact with respirable air. When boiling it emits fumes, and calcines very rapidly. It may be granulated by being poured into a wooden box, and agitated. During congelation it is brittle, so that the parts will separate by the stroke of a hammer; and by this means the form of its crystals may be discovered.

In the progress of calcination it first becomes a dusky grey powder, then yellow, when it is called *massicot*; then, by imbibing pure air, it becomes red, and is called *minium*, or *red lead*. In a greater degree of heat it becomes

massicot

maſſicot again, having parted with its pure air. If the heat be too great, and applied rapidly, it becomes a flaky ſubſtance, called *litharge*; and with more heat it becomes a *glaſs*, which readily unites with metallic calces and earth, and is a principal ingredient in the manufacture of *flint glaſs*, giving it its peculiar denſity and refractive power.

Though lead ſoon tarniſhes, the imperfect calx thus made does not ſeparate from the reſt of the metal, and therefore protects it from any farther action of the air, by which means it is very uſeful for the covering of houſes, and other ſimilar purpoſes. All acids act upon lead, and form with it different ſaline ſubſtances. *White-lead* conſiſts of its union with vinegar and pure air. Alſo diſſolved in vinegar, and cryſtallized, it becomes *ſugar of lead*, which, like all the other preparations of this metal, is a deadly poiſon.

Oils

Oils diſſolve the calces of lead, which, by this means, is the baſis of paints, plaiſters, &c.

By means of heat litharge decompoſes common ſalt, the lead uniting with the marine acid, and forming a yellow ſubſtance, uſed in painting, and by this means the foſſil alkali is ſeparated.

Lead unites with moſt metals, though not with iron. Two parts of lead and one of tin make a *ſolder*, which melts with leſs heat than either of the metals ſeparately; but a compoſition of eight parts of biſmuth, five of lead, and three of tin, makes a metal which melts in boiling water.

This metal will be diſſolved by water if it contain any ſaline matter, and the drinking of it occaſions a peculiar kind of cholic.

Lead is ſometimes found native, but generally minerally mineralized with
fulphur

fulphur or arfenic, and often mixed with a fmall quantity of filver.

## *Of Copper.*

COPPER is a metal of a reddifh or brownifh colour, confiderably fonorous, and very malleable.

At a heat far below ignition, the furface of copper becomes covered with a range of prifmatic colours, the commencement of its calcination; and with more heat a black fcale is formed, which eafily feparates from the metal, and in a ftrong heat it melts, and burns with a bluifh green flame.

Copper rufts by expofure to the air; but the partially calcined furface adheres to the metal, as in the cafe of lead, and thus preferves it from farther corrofion.

Copper diffolved in the vitriolic acid forms cryftals of a blue colour, called *blue copperas.* From this folution it is precipitated by iron, which by this means becomes coated with copper. The nitrous acid diffolves copper with moft rapidity, producing nitrous air. If the folution be diftilled, almoft all the acid will be retained in the refiduum, which is white; but more heat will expel the acid, chiefly in the form of dephlogifticated air, and the remainder will be a black fubftance, confifting of the pure calx of copper. The vegetable acids diffolve copper as well as the mineral ones, which makes the ufe of this metal for culinary purpofes in fome cafes dangerous. To prevent this they give it a coat of tin. The folution of copper in the vegetable acid is called *verdigris.*

Alkalis diffolve copper as well as acids. With the volatile alkali a blue liquor is formed, but in fome cafes it becomes colourlefs. All the circumftances

cumstances of this change of colour have not yet been examined. Both oil and sulphur will dissolve copper, and with the latter it forms a blackish grey compound, used by dyers.

Copper readily unites with melted tin, at a temperature much lower than that which is necessary to melt the copper; by which means copper vessels are easily covered with a coating of tin. A mixture of copper and tin, called *bronze*, the specific gravity of which is greater than that of the medium of the two metals, is used in casting statues, cannon, and bells; and in a certain proportion this mixture is excellent for the purpose of mirrors of reflecting telescopes, receiving a fine polish, and not being apt to tarnish. Copper and arsenic make a brittle compound called *tombach*; and with zinc it makes the useful compound commonly called *brass*, in which zinc is about one third of its weight.

Copper is fometimes found native; but commonly mixed with fulphur, in ores of a red, green, or blue colour.

Copper being an earlier difcovery than that of iron, was formerly ufed for weapons and the fhoeing of horfes; and the ancients had a method, with which we are not well acquainted, of giving it a confiderable degree of hardnefs, fo that a fword made of it might have a pretty good edge.

LECTURE

# LECTURE XXV.

## *Of Iron.*

IRON is a metal of a bluish colour, of the greatest hardness, the most variable in its properties, and the most useful of all the metals; so that without it it is hardly possible for any people to make great advances in arts and civilization.

This metal readily parts with its phlogiston, so as to be very subject to calcine, or rust, by exposure to the air. The same is evident by the colours which appear on its surface when exposed to heat, and also when it is struck with flint; the particles that fly from it being iron partially calcined. In consequence of its readily parting with its phlogiston, it is capable of burning, like wood or other fuel, in pure air.

Iron and platina have the property of *welding* when very hot, so that two pieces may be joined without any solder.

When iron is heated in contact with steam, part of the water takes the place of the phlogiston, while the rest unites with it, and makes inflammable air. B ythis means the iron acquires one third more weight, and becomes what is called *finery cinder*. This substance, heated in inflammable air, imbibes it, parts with its water, and becomes perfect iron again. If the iron be heated in pure air, it also imbibes the water, of which that air chiefly consists, and also a portion of the peculiar element of the pure air.

The solution of iron in spirit of vitriol produces *green copperas*; which being calcined, becomes a red substance, called *colcothar*.

The precipitate of iron, by an infusion of galls, is the colouring matter in *ink*, which is kept suspended by means of gum. The precipitate from the
                                    same

fame folution by phlogifticated alkali, is *Pruffian blue*.

Water faturated with fixed air diffolves iron, and makes a pleafant chalybeat.

The calx of iron gives a green colour to glafs.

Iron readily combines with fulphur. When they are found combined by nature, the fubftance is called *pyrites*.

The union of phofphoric acid with iron makes it brittle when cold, commonly called *cold fhort*; and the union of arfenic makes it brittle when hot, thence called *red fhort*.

Iron unites with gold, filver, and platina, and plunged in a white heat into mercury, it becomes coated with it; and if the procefs be frequently repeated, it will become brittle, which fhews that there is fome mutual action between them.

G                                    Iron

Iron readily unites with tin; and by dipping thin plates of iron into melted tin, they get a complete coating of it, and make the *tinned plates* in common use.

When crude iron comes from the smelting furnace it is brittle; and when it is white within, it is extremely hard; but when it has a black grain, owing to its having more phlogiston, it is softer, and may be filed and bored.

Cast iron becomes *malleable* by being exposed to a blast of air when nearly melting; the consequence of which is a discharge of inflammable air, and the separation of a liquid substance, which, when concreted, is called *finery cinder*. The iron generally loses one fourth of its weight in the process. Crude iron contains much *plumbago*, and the access of pure air probably assists in discharging it, by converting it into air, chiefly inflammable.

Malleable

Malleable iron, expofed to a red heat in contact with charcoal, called *cementation*, converts it into *steel*, which has the properties of becoming much harder than iron, and very elaftic, by being firft made very hot, and then fuddenly cooled, by plunging it in cold water. By firft making it very hard, and then giving different degrees of heat, and cooling it in thofe different degrees, it is capable of a great variety of *tempers*, proper for different ufes. Of the degrees of heat workmen judge by the change of colour on its furface. Steel, like crude iron, is capable of being melted without lofing its properties. It is then called *caft steel*, and is of a more uniform texture. Iron acquires fome little weight by being converted into fteel; and when diffolved in acid, it yields more plumbago. Steel has fomething lefs fpecific gravity than iron. If the cementation be continued too long, the fteel acquires a darkifh fracture, it is more fufible, and incapable of welding. Steel heated in contact with eartny matters, is reduced to iron.

Iron

Iron is the only fubftance capable of *magnetifm*; and hardened fteel alone is capable of retaining magnetifm. The loadftone is an ore of iron.

LECTURE

# LECTURE XXVI.

## Of Tin.

TIN is a metal of a slightly yellowish cast, though harder than lead, very malleable, but of no great tenacity; so that wires cannot be made of it. It easily extends under the hammer, and plates of it, called *tinfoil*, are made only one thousandth part of an inch thick, and might be made as thin again.

Tin has less specific gravity than any other metal. It melts long before ignition, at 410 of Fahrenheit, and by the continuance of heat is slowly converted into a white powder, which is the chief ingredient in *putty*, used in polishing, &c. Like lead, it is brittle when heated a little short of fusion, and may be reduced into grains by agitation as it passes from a fluid to a solid state.

The

The calx of tin refifts fufion more than that of any other metal, which makes it ufeful in making an opaque white enamel.

Tin lofes its bright furface when expofed to the air, but is not properly fubject to ruft; fo that it is ufeful in protecting iron and other metals from the effects of the atmofphere.

Concentrated vitriolic acid, affifted by heat, diffolves half its weight of tin, and yields vitriolic acid air. With more water it yields inflammable air. During the folution, the phlogifton of the tin uniting with the acid, forms fulphur, which makes it turbid. By long ftanding, or the addition of water, the calx of tin is precipitated from the folution. The nitrous acid diffolves tin very rapidly without heat, and yields but little nitrous air. With marine acid this metal yields inflammable air. With aqua regia it affumes the form of a gelatinous fubftance ufed by dyers to heighten the colour of fome red tinctures, fo as to produce a bright fcarlet in dying wool.

A tranf-

A tranſparent liquor, which emits very copious fumes, called, from the inventor, *the ſmoaking liquor of Liba-vius*, is made by diſtilling equal parts of amalgam of tin and mercury with cor-roſive ſublimate, triturated together. A colourleſs liquor comes over firſt, and then a thick white fume, which con-denſes into the tranſparent liquor above mentioned. M. Adet has ſhewn, that this liquor bears the ſame relation to the common ſolution of tin, that cor-roſive ſublimate does to calomel, and has given an ingenious ſolution of many of its properties.

Tin detonates with nitre; and if the cryſtals made by the ſolution of copper in the nitrous acid be incloſed in tinfoil, nitrous fumes will be emitted, and the whole will become red hot. Alſo if five times its weight of ſulphur be ad-ded to melt tin, a black brittle com-pound, which readily takes fire, will be formed.

G 4      Another

Another combination of tin, fulphur, and mercury, makes a light yellow fub-ftance, called *aurum mufivum*, ufed in painting.

Tin is the principal ingredient in the compofition of *pewter*, the other ingre-dients being lead, zinc, bifmuth, and copper, each pewterer having his pecu-liar receipt. It is alfo ufed in coating copper and iron plates, and in filvering looking-glaffes, befides being caft into a variety of forms, when it is called *block tin*.

Tin is fometimes found native, but is generally mineralized with fulphur and arfenic. The latter is thought to be always contained in tin, and to be the caufe of the crackling noife made by bending plates of it.

*Of*

## *Of the Semi-metals.*

BISMUTH is a femi-metal of a yellow-ifh or reddifh caft, but little fubject to change in the air, harder than lead, but eafily broken, and reducible to powder. When broken it exhibits large fhining facets, in a variety of pofitions. Thin pieces of it are confiderably fonorous.

Bifmuth melts at about 460° of Fahrenheit. With more heat it ignites, and burns with a flight blue flame, while a yellow calx, called *flowers of bifmuth*, is produced. With more heat it becomes a greenifh glafs. In a ftrong heat, and in clofe veffels, this metal fublimes.

Vitriolic acid, even concentrated and boiling, has but little effect upon bif-

muth;

muth; but the nitrous acid acts upon it with the greatest rapidity and violence, producing much nitrous air, mixed with phlogisticated nitrous vapour. From the solution of bifmuth in this acid, a white fubftance, called *magiftery of bifmuth*, is precipitated by the affufion of water. This has been ufed as a paint for the fkin, but has been thought to injure it.

The marine acid does not readily act upon bifmuth; but when concentrated, it forms with it a faline combination, which does not eafily cryftallize, but may be fublimed in the form of a foft fufible falt, called *butter of bifmuth*.

Bifmuth unites with moft metallic fub-ftances, and in general renders them more fufible. When calcined with the imperfect metals, it unites with them, and has the fame effect as lead in cupel-lation.

Bifmuth

Bismuth is used in the composition of pewter, in printers' types, and other metallic mixtures.

This metal is sometimes found native, but more commonly mineralized with sulphur.

LECTURE

# LECTURE XXVII.

## Of Nickel.

Nickel is a femi-metal of a reddifh cift, of great hardnefs, and always magnetical; on which account it is fuppofed to contain iron, though chemifts have not yet been able to feparate them.

The pureft nickel is fo infufible as not to run into a mafs in the ftrongeft heat of a fmith's forge; but then it is in fome degree malleable.

Concentrated acid of vitriol only corrodes nickel. Alkalis precipitate it from its folution in the nitrous acid, and diffolve the precipitate. It readily unites with fulphur.

Nickel

Nickel is found either native or mineralized with several other metals, especially with copper, when it is called *kupfer nickel*, or *false copper*, being of a reddish or copper colour.

This semi-metal has not yet been applied to any use.

## Of Arsenic.

WHAT is commonly called *arsenic* is the calx of a semi-metal called the *regulus of arsenic*. It is a white and brittle substance, expelled from the ores of several metals by heat. It is then refined by a second sublimation, and melted into the masses in which it is commonly sold. This calx is soluble in about eighty times its weight of cold water, or in fifteen times its weight of boiling water. It acts in many respects like an acid, as it decomposes nitre by distillation, when the nitrous acid

acid flies off, and the *arsenical salt of Macquer* remains behind.

When the calx of arsenic is diftilled with fulphur, the vitriolic acid flies off, and a fubftance of a yellow colour, called *orpiment*, is produced. This appears to confift of fulphur and the regulus of arfenic; part of the fulphur receiving pure air from the calx, to which it communicates phlogifton; and thus the fulphur becomes converted into vitriolic acid, while the arfenical calx is reduced, and combines with the reft of the fulphur.

The combination of fulphur and arfenic, by melting them together, is of a red colour, known by the name of *realgal*, or *realgar*. It is lefs volatile than orpiment.

The folution of fixed alkali diffolves the calx of arfenic, and by means of heat a brown tenacious mafs is produced, and having alfo a difagreeable fmell, it is called *liver of arfenic*.

The

The regulus of arfenic is of a yellow colour, fubject to tarnifh or grow black, by expofure to the air, very brittle, and of a laminated texture. In clofe veffels it wholly fublimes, but burns with a fmall flame in pure air.

Vitriolic acid has little action upon this femi-metal, except when hot; but the nitrous acid acts readily upon it, and likewife diffolves the calx, as does boiling marine acid, though it affects it very little when cold.

Moft of the metals unite with the regulus of arfenic.

Dephlogifticated marine acid converts the calx of arfenic into *arfenical acid* by giving it pure air.

The acid of arfenic acts more or lefs upon all metals, but the phenomena do not appear to be of much importance.

The

The calx of acid is ufed in a variety of the arts, efpecially in the manufactory of glafs. Orpiment and realgar are ufed as pigments. Some attempts have been made to introduce it into medicine, but being dangerous, the experiments fhould be made with caution.

## Of Cobalt.

COBALT is a femi-metal of a grey or fteel colour, of a clofe-grained fracture, more difficult of fufion than copper, not eafily calcined. It foon tarnifhes in the air, but water has no effect upon it.

Cobalt, diffolved in *aquã regia*, makes an excellent fympathetic ink, appearing green when held to the fire, and difappearing when cold, unlefs it has been heated too much, when it burns the paper.

The

The calx of cobalt is of a deep blue colour, which, when fufed, makes the blue glafs called *fmalt*. The ore of cobalt, called *zaffre*, is found in feveral parts of Europe, but chiefly in Saxony. As it is commonly fold, it contains twice or thrice its weight of powder of flints. The fmalt is ufually compofed of one part of calcined cobalt, fufed with two parts of powder of flint and one of potafh.

The chief ufe of cobalt is for making fmalt; but the powder and the bluestone ufed by laundreffes is a preparation made by the Dutch of a coarfe kind of fmalt.

## *Of Zinc.*

ZINC is a femi metal of a bluifh caft, brighter than lead, and fo far malleable as not to be broken by a hammer, though it cannot be much extended. When broken by bending, it appears to confift of cubical grains. If it be

heated

heated nearly to melting, it will be suf-
ficiently brittle to be pulverized.    It
melts long before ignition, and when it
is red hot, it burns with a dazzling white
flame, and is calcined with such rapi-
dity, that its calx flies up in the form
of white flowers, called *flowers of zinc*,
or *philosophical wool.* · In a stronger
heat they become a clear yellow glafs.
Heated in clofe veffels, this metal rifes
without decompofition, being the moft
volatile of all the metals except the re-
gulus of *arfenic.*

Zinc diffolved in diluted vitriolic acid,
yields much inflammable air, and has
a refiduum, which appears to be plum-
bago, and the liquor forms cryftals, called
*white copperas.*    This metal alfo yields
inflammable air when diffolved in the
marine acid.    Diffolved in the nitrous
acid, it yields dephlogifticated nitrous
air, with very little proper nitrous air.

The ore of zinc, called *calamine*,
is generally of a white colour; and the
chief ufe of it is to unite it with copper,
with

with which it makes brafs and other gold-coloured mixtures of metals. The calx and the falts of this metal are occafionally ufed in medicine.

LECTURE

## LECTURE XXVIII.

### Of Antimony.

T HE regulus of antimony is of a fil-
very white colour, of a fcaly texture,
very brittle, and melts foon after ig-
nition.    By continuance of heat it cal-
cines in white fumes, called *argentine
flowers of antimony*, which melt into a
hyacinthine glafs.    In clofe veffels it
rifes without decompofition.    Its calx
is foluble in water, like that of arfe-
nic.    This metal tarnifhes, but does
not properly ruft, by expofure to the
air.

This metal is foluble in aqua regia.
It detonates with nitre, and what re-
mains of equal parts of nitre and re-
gulus of antimony after detonation, in
a hot crucible, is called *diaphoretic
antimony*.    The water ufed in this pre-
paration contains a portion of the
calx fufpended by the alkali, and be-
ing

ing precipitated by an acid, is called *cerufe of antimony*.

When regulus of antimony is pulverized and mixed with twice its weight of corrofive fublimate (which is attended with heat) and then diftilled with a gentle fire, a thick fluid comes over, which is congealed in the receiver, or in the neck of the retort, and is called *butter of antimony*. The refiduum confifts of revived mercury, with fome regulus and calx of antimony. When this butter of antimony is thrown into pure water, there is a white precipitate, called *powder of algaroth*, a violent emetic. Nitrous acid diffolves the butter of antimony; and when an equal weight of nitrous acid has been three times diftilled to drynefs from butter of antimony, the refiduum, after ignition, is called *bezoar mineral*, and feems to be little more than a calx of the metal.

Crude antimony, which has been much ufed in the experiments of
alchemifts,

alchemifts, is a combination of ful-
phur and regulus of antimony. Heat
melts it, and finally converts it into
glafs, of a dark red colour, called *liver
of antimony.* If antimony be melted
or boiled with a fixed alkali, a preci-
pitate is made by cooling, called *kermes
mineral,* formerly ufed in medicine.
The antimonial preparations that are
now moft in ufe are *antimonial wine*
and *tartar emetic.* The wine is made
by infufing pulverized glafs of anti-
mony in Spanifh wine fome days, and
filtering the clear fluid through pa-
per. The emetic tartar, or antimo-
nial tartar, is a faline fubftance, com-
pofed of acid of tartar, vegetable al-
kali, and antimony partially calcined.
The preparation may be feen in the
Difpenfaries.

The regulus of antimony is ufed
in the form of pills, which purge
more or lefs in proportion to the acid
they meet with; and as they under-
go little or no change in paffing
through

through the body, they are called *per-petual pills.*

## Of Manganese.

MANGANESE is a hard, black mineral, very ponderous, and the regulus of it is a femi-metal of a dull white colour when broken, but foon grows dark by expofure to the air. It is hard and brittle, though not pulverizable, rough in its fracture, and of very difficult fufion. Its calces are white when imperfect, but black, or dark green, when perfect. The white calx is foluble in acids. When broken in pieces, it falls into powder by a fpontaneous calcination, and this powder is magnetical, though the mafs was not poffeffed of that property. The black calx of manganefe is altogether infoluble in acids. It contains much dephlogifticated air.

The calx of manganefe is ufed in making glafs; the glafs deftroying the
colour

colour of that of the other materials, and thereby making the whole mafs tranfparent.

This femi-metal mixes with moft of the metals in fufion, but not with mercury.

There is another ore of manganefe, called *black woad*, which inflames fpon-taneoufly when mixed with oil.

## Of Wolfram.

WOLFRAM is a mineral of a brown-ifh or black colour, found in the tin mines of Cornwall, of a radiated or foliated texture, fhining almoft like a metal. It contains much of the calx of manganefe, and iron; but when the fubftance is pulverized, thefe are eafily diffolved, and the calx of wol-fram is found to be yellow.

This calx turns blue by expofure to light; and an hundred grains of it
<div align="right">heated</div>

heated with charcoal will yield fixty grains of a peculiar metal, in fmall particles, which, when broken, look like fteel. It is foluble in the vitriolic or marine acids, and reduced to a yellow calx by nitrous acid or aqua regia.

## Of Molybdena.

MOLYBDENA is a fubftance which much refembles plumbago; but its texture is fcaly, and not eafily pulverized, on account of a degree of flexibility which its laminæ poffefs. With extreme heat, and mixed with charcoal, it yields fmall particles of a metal that is grey, brittle, and extremely infufible; and uniting with feveral of the metals, it forms with them brittle or friable compounds. By heat it is converted into a white calx.

Of

## Of Solid Combustible Substances.

THERE yet remains a class of solid substances, of the *combustible* kind, but most of them have been already considered under the form of the fluids, from from which they are originally formed, as *bitumen*, *pit-coal*, and *amber*; or under the principal ingredients of which they are composed, as *sulphur* and *plumbago*.

There only remains to be mentioned the *diamond*, which is of a nature quite different from that of the other precious stones, the principal ingredient in which is siliceous earth, which renders them not liable to be much affected by heat. On the contrary, the diamond is a combustible substance; for in a degree of heat somewhat greater than that which will melt silver, it burns with a slight flame, diminishes common air, and leaves a soot behind. Also, if diamond powder be triturated with

with vitriolic acid, it turns it black, which is another proof of its containing phlogiston.

The diamond is valued on account of its extreme hardness, the exquisite polish it is capable of, and its extraordinary refractive power; for light falling on its interior surface with an angle of incidence greater than $24\frac{1}{2}$ will be wholly reflected, whereas in glass it requires an angle of 41 degrees.

# LECTURE XXIX.

*Of the Doctrine of Phlogiston and the
Compofition of Water.*

IT was fuppofed to be a great difcovery
of Mr. Stahl, that all inflammable fub-
ftances, as well as metals, contain a prin-
ciple, or fubftance to which he gave
the name of phlogifton, and that the
addition or deprivation of this fubftance
makes fome of the moft remarkable
changes in bodies, efpecially that the
union of a metallic calx and this fub-
ftance makes a metal; and that com-
buftion confifts in the feparation of
phlogifton from the fubftances that con-
tain it. - That it is the fame principle,
or fubftance, that enters into all inflam-
mable fubftances, and metals, is evi-
dent, from its being difengaged from

any

any of them, and entering into the composition of any of the others. Thus the phlogiston of charcoal or inflammable air becomes the phlogiston of any of the metals, when the calx is heated in contact with either of them.

On the contrary, Mr. Lavoisier and most of the French chemists, are of opinion, that there is no such principle, or substance, as phlogiston; that metals and other inflammable bodies are simple substances, which have an affinity to pure air; and that combustion consists not in the separation of any thing from the inflammable substance, but in the union of pure air with it.

They moreover say, that water is not, as has been commonly supposed, a simple substance, but that it consists of two elements, viz. pure air, or *oxygene*, and another, to which they give the name of *hydrogene*, which, with the principle of *heat*, called by them *calorique*, is inflammable air.

H 3 The

The principal fact adduced by them to prove that metals do not lofe any thing when they become calces, but only gain fomething, is, that mercury becomes a calx, called *precipitate per fe,* by imbibing pure air, and that it becomes running mercury again by parting with it.

This is acknowledged: but it is almoft the only cafe of any calx being revived without the help of fome known phlogiftic fubftance; and in this particular cafe it is not abfurd to fuppofe, that the mercury, in becoming precipitate per fe, may retain all its phlogifton, as well as imbibe pure air, and therefore be revived by fimply parting with that air. In many other cafes the fame metal, in different ftates, contains more or lefs phlogifton, as caft iron, malleable iron, and fteel. Alfo there is a calx of mercury made by the acid of vitriol, which cannot be revived without the help of inflammable air, or fome other fubftance fuppofed to contain phlogifton: and that the

the inflammable air is really imbibed in these processes, is evident, from its wholly disappearing, and nothing being left in the vessel in which the process is made beside the metal that is revived by it. If precipitate per se be revived in inflammable air, the air will be imbibed, so that running mercury may contain more or less phlogiston.

The antiphlogistians also say, that the diminution of atmospherical air by the burning of phosphorus is a proof of their theory; the pure air being imbibed by that substance, and nothing emitted from it. But there is the same proof of phosphorus containing phlogiston, that there is of dry flesh containing it: since the produce of the solution of it in nitrous acid, and its effect upon the acid, are the same, viz. the production of phlogisticated air, and the phlogistication of the acid.

Their proof that water is decomposed, is, that in sending steam over hot iron, inflammable air (which they

suppose

suppose to be one constituent part of it)
is procured; while the other part, viz.
the oxygene, unites with the iron, and
adds to its weight. But it is replied,
that the inflammable air may be well
supposed to be the phlogiston of the
iron, united to part of the water, as
its base, while the remainder of the
water is imbibed by the calx; and that
it is mere water, and not pure air, or
oxygene, that is retained in the iron,
is evident, from nothing but pure
water being recovered when this calx
of iron is revived in inflammable air,
in which case the inflammable air wholly
disappears, taking the place of the
water, by which it had been expelled.

In answer to this it is said, that the
pure air expelled from the calx uniting
with the inflammable air in the vessel,
recomposes the water found after this
process. But in every other case in
which any substance containing pure air
is heated in inflammable air, though
the inflammable air be in part imbibed,
some *fixed air* is produced, and this
fixed

fixed air is compofed of the pure air in the fubftance and part of the inflam·mable air in the veffel. Thus, if *minium,* which contains pure air, and *maf-ficot,* which contains none, be heated in inflammable air, in both the cafes lead will be revived by the ab-forption of inflammable air; but in the former cafe only, and not in the latter, will fixed air be produced. The calx of iron, therefore, having the fame effect with maflicot, when treated in the fame manner, appears to contain no more pure air than maflicot does.

Befides this explanation of the facts on which the new theory is founded, which fhews it to be unneceffary, the old hypothefis being fufficient for the purpofe, fome facts are alledged, as in-confiftent with the new doctrine.

If the calx of iron made by water, and charcoal made by the greateft de-gree of heat, be mixed together, a great quantity of inflammable air will be produced; though, according to

the

the new theory, neither of thefe fub-
ftances contained any water, which
they maintain to be the only origin of
it. But this fact is eafily explained
upon the doctrine of phlogifton; the
water in this calx uniting with the phlo-
gifton of the charcoal, and then form-
ing inflammable air; and it is the fame
kind of inflammable air that is made
from charcoal and water.

Alfo the union of inflammable and
pure air, when they are fired together
by means of the electric fpark, produ-
ces not pure water, as, according to
the new theory, it ought to do, but *ni-
trous acid*.

To this it has been objected, that
the acid thus produced came from the
decompofition of phlogifticated air, a
fmall portion of which was at firft con-
tained in the mixture of the two kinds
of air. But when every particle of
phlogifticated air is excluded, the
ftrongeft acid is procured.

They

They find, indeed, that by the flow burning of inflammable air in pure air, they get pure water. But then it appears, that whenever this is the cafe, there is a production of phlogisticated air, which contains the neceffary element of nitrous acid; and this is always the cafe when there is a little furplus of the inflammable air that is fired along with the pure air, as the acid is always procured when there is a redundancy of pure air.

That much water fhould be procured by the decompofition of thefe kinds of air, is eafily accounted for, by fuppofing that water, or fteam, is the bafis of thefe, as well as of all other kinds of air.

Since air fomething better than that of the atmofphere is conftantly produced from water by converting it into vapour, and alfo by removing the preffure of the atmofphere, and thefe proceffes do not appear to have any limits; it feems probable, that *water* united to the principle of *heat*, conftitutes atmof-
pherical

pherical air; and if fo, it muft confift of the elements of both dephlogifticated and phlogifticated air; which is a fuppofition very different from that of the French chemifts.

# LECTURE XXX.

## Of Heat.

HEAT is an affection of bodies well known by the fenfation that it excites. It is produced by friction or compreffion, as by the ftriking of flint againft fteel, and the hammering of iron, by the reflection or refraction of light, and by the combuftion of inflammable fubftances.

It has been long difputed, whether the caufe of heat be properly a *fubftance*, or fome particular affection of the particles that compofe the fubftance that is heated. But be it a fubftance, or a principle of any other kind, it is capable of being transferred from one body to another, and the communication of it is attended with the following circumftances.

circumſtances. All ſubſtances are expanded by heat, but ſome in a greater degree than others; as metals more than earthy ſubſtances, and charcoal more than wood. Alſo ſome receive and tranſmit heat through their ſubſtance more readily than others; metals more ſo than earths, and of the metals, copper more readily than iron. Inſtruments contrived to aſcertain the expanſion of ſubſtances by heat, are called *pyrometers*, and are of various conſtructions.

As a ſtandard to meaſure the degrees of heat, mercury is in general preferable to any other ſubſtance, on account of its readily receiving, and communicating, heat through its whole maſs. *Thermometers*, therefore, or inſtruments to meaſure the degrees of heat, are generally conſtructed of it, though, as it is ſubject to become ſolid in a great degree of cold, ardent ſpirit, which will not freeze at all, is more proper in that particular caſe.

The

The graduation of thermometers is arbitrary. In that of Fahrenheit, which is chiefly ufed in England, the freezing point of water is 32°, and the boiling point 212°. In that of Reaumur, which is chiefly ufed abroad, the freezing point of water is o, and the boiling point 80. To meafure the degrees of heat above ignition, Mr. Wedgwood has happily contrived to ufe pieces of clay, which contract in the fire; and he has alfo been able to find the coincidence of the degrees in mercurial thermometers with thofe of his own.

To meafure the degrees of heat and cold during a perfon's abfence, Lord George Cavendifh contrived an inftrument, in which a fmall bafon received the mercury, that was raifed higher than the place for which it was regulated by heat or cold, without a power of returning. But Mr. Six has lately hit upon a better method, viz. introducing into the tube of his thermometer a fmall piece of iron, which is raifed by the

the afcent of the mercury, and prevent-
ed from defcending by a fmall fpring;
but which may be brought back to its
former place by a magnet acting through
the glafs.

Heat, like light, is propagated in
right lines; and what is more remarka-
ble, cold obferves the fame laws.    For
if the fubftance emitting heat without
light, as iron below ignition, be placed
in the focus of a burning mirror, a
thermometer in the focus of a fimilar
mirror, placed parallel to it, though at
a confiderable diftance, will be heated
by it, and if a piece of ice be placed
there the mercury will fall.

Heat affifts the folvent power of al-
moft all menftrua; fo that many fub-
ftances will unite in a certain degree of
heat, which will form no union at all
without it, as dephlogifticated and in-
flammable air.

If fubftances be of the fame kind,
they will receive heat from one another,
in proportion to their maffes.    Thus,
if

if a quantity of water heated to 40° be mixed with another equal quantity of water heated to 20°, the whole mafs will be heated to 30°. But if the fubftances be of different kinds, they will receive heat from each other in different proportions, according to their *capacity* (as it is called) of receiving heat. Thus, if a pint of mercury of the temperature of 136 be mixed with a pint of water of the temperature of 50, the temperature of the two after mixture will not be a medium between thofe two numbers, viz. 93, but 76; confequently the mercury was cooled 60°, while the water was heated only 26; fo that 26 degrees of heat in water correfpond to 60 in mercury. But mercury is about 13 times fpecifically heavier than water, fo that an equal weight of mercury would contain only one thirtieth part of this heat; and dividing 26 by 13, the quotient is 2. If *weight*, therefore, be confidered, the heat difcovered by water fhould be reckoned as 2 inftead of 60; and confequently when water receives two degrees of heat, an

equal

equal weight of mercury will receive 60°
and dividing both the numbers by 2, if
the heat of water be 1, that of the mer-
cury will be 30. Or fince they receive
equal degrees of heat, whether they dif-
cover it or not (and the lefs they difco-
ver, the more they retain in a latent
ftate) a pound of mercury contains no
more than one thirtieth part of the heat
actually exifting in a pound of water of
the fame temperature. Water, there-
fore, is faid to have a greater capacity
for receiving and retaining heat, without
difcovering it, than mercury, in the pro-
portion of 30 to 1, if weight be confi-
dered, or of 60 to 26, that is of 30 to
13; if *bulk* be the ftandard, though,
according to fome, it is as 3 to 2.

The capacity of receiving heat in the
fame fubftance is greateft in a ftate of
vapour, and leaft in that of a folid; fo
that when ice is converted into water,
heat is abforbed, and more ftill when it
is converted into vapour; and on the
contrary, when vapour is converted into
water, it gives out the heat which it had
imbibed,

imbibed, and when it becomes ice it gives out ftill more.

If equal quantities of ice and water be expofed to heat at the temperature of 32°, the ice will only become water, without receiving any additional fenfible heat; but an equal quantity of water in the fame fituation would be raifed to 178°; fo that 146 degrees of heat will be imbibed, and remain latent in the water, in confequence of its paffing from a ftate of ice: and heat communicated by a given weight of a vapour will raife an equal weight of a non-evaporable fub-ftance, of the fame capacity with water, 943 degrees; fo that much more heat is latent in fteam, than in the water from which it was formed.

This doctrine of latent heat explains a great variety of phænomena in nature; as that of cooling bodies by evaporation, the vapour of water, or any other fluid fubftance, abforbing and carrying off the heat they had before.

Water,

Water, perfectly at rest, will fall confiderably below the freezing point, and yet continue fluid: but on the flighteft agitation, the congelation of the whole, or part of it, takes place inftantly, and if the whole be not folid, it will inftantly rife to 32°, the freezing point. From whatever caufe, fome motion feems neceffary to the commencement of congelation, at leaft in a moderate temperature; but whenever any part of the water becomes folid, it gives out fome of the heat it had before, and that heat which was before latent becoming fenfible, and being diffufed through the whole mafs, raifes its temperature.

On the fame principle, when water heated higher than the boiling point in a digefter is fuddenly permitted to efcape in the form of fteam, the remainder is inftantly reduced to the common boiling point, the heat above that point being carried off in a latent ftate by the fteam.

Had it not been for this wife provifion in nature, the whole of any quantity

of

of water would, in all cafes of freezing, have become folid at once; and alfo the whole of any quantity that was heated to the point of boiling, would have been converted into fteam at once; circumftances which would have been extremely inconvenient, and often fatal.

This doctrine alfo explains the effect of freezing mixtures, as that of falt and fnow. Thefe folid fubftances, on being mixed, become fluid, and that fluid abforbing much heat, deprives all the neighbouring bodies of part of what they had. But if the temperature at which the mixture is made be as low as that to which this mixture would have brought it, it has no effect, and in a lower temperature this new fluid would become folid; for that mixture has only a certain determinate capacity for heat, and if the neighbouring bodies have lefs heat, they will take from it.

It has been obferved, that the comparative heat of bodies containing phlogifton is increafed by calcination or combuftion;

buſtion ; ſo that the calx of iron has a greater capacity for heat, and therefore contains more latent heat, than the metal.

In general it is not found, that the ſame ſubſtances have their capacity for receiving heat increaſed by an increaſe of temperature ; but this is ſaid to be the caſe with a mixture of ardent ſpirit and water, and alſo that of ſpirit of vitriol and water.

Since all ſubſtances contain a greater or leſs quantity of heat, and in conſe-quence of being deprived of it become colder and colder, it is a queſtion of ſome curioſity to determine the extent to which this can go, or at what degree in the ſcale of a thermometer any ſubſtance would be abſolutely cold, or deprived of all heat ; and an attempt has been made to ſolve this problem in the fol-lowing manner.    Comparing the capa-city of water with that of ice, by means of a third ſubſtance, viz. mercury, it has been found, that if that of ice be 9°, that of water is 10°; ſo that water

in

in becoming ice gives out one tenth part of its whole quantity of heat. But it has been shown, that ice in becoming water absorbs 146 degrees of heat. This, therefore, being one tenth part of the whole heat of water, it must have contained 1460 degrees; so that taking 32 degrees, which is the freezing point, from that number, the point of absolute cold will be 1426 below 0 of Fahrenheit's scale.

By a computation, made by means of the heat of inflammable and dephlogisticated air, at the temperature of 50, Dr. Crawford finds, that it contains nearly 1550 degrees of heat; so that the point of absolute cold will be 1500 below 0. But more experiments are wanted to solve this curious problem to entire satisfaction.

LECTURE

# LECTURE XXXI.

## *Of Animal heat.*

Since all animals, and especially those that have red blood, are much hotter than the medium in which they live, the source of this heat has become the subject of much investigation; and as the most probable theory is that of Dr. Crawford, I shall give a short detail of the reasons on which it is founded.

Having, with the most scrupulous attention, ascertained the *latent*, or, as he calls it, the *absolute* heat of blood, and also that of the aliments of which it is composed, he finds that it contains more than could have been derived from *them*. Also finding that the absolute heat of arterial blood exceeds that of venous blood, in the proportion of $11\frac{1}{2}$ to 10,

he

he concludes that it derives its heat from the air respired in the lungs, and that it parts with this *latent* heat, so that it becomes sensible, in the course of its circulation, in which it becomes loaded with phlogiston, which it communicates to the air in the lungs.

That this heat is furnished by the *air*, he proves, by finding, that that which we inspire contains more heat than that which we expire, or than the aqueous humour which we expire along with it, in a very considerable proportion; so that if the heat contained in the pure air did not become latent in the blood, it would raise its temperature higher than that of red-hot iron. And again, if the venous blood, in being converted into arterial blood, did not receive a supply of latent heat from the air, its temperature would fall from 96 to 104 below 0 in Fahrenheit's thermometer.

That the heat procured by combustion has the same source, viz. the dephlogisticated air that is decomposed in the

process,

procefs, is generally allowed; and Dr.
Crawford finds, that when equal por-
tions of air are altered by the respiration
of a Guinea pig, or by the burning of
charcoal, the quantity of heat commu-
nicated by the two proceffes is nearly
equal.

The following facts are alfo alleged
in favour of his theory. Whereas ani-
mals which have much red blood, and
refpire much, have the power of keep-
ing themfelves in a temperature confi-
derably higher than that of the fur-
rounding atmofphere, other animals, as
*frogs* and *ferpents*, are nearly of the
fame temperature with it; and thofe
animals which have the largeft refpira-
tory organs, as birds, are the warmeft;
alfo the degree of heat is in fome mea-
fure proportionable to the quantity of
air that is refpired in a given time, as in
violent exercife.

It has been obferved, that animals in
a medium hotter than the blood have a
power of preferving themfelves in the
fame

fame temperature.   In this cafe the heat
is probably carried off by perfpiration,
while the blood ceafes to receive, or give
out, any heat; and Dr. Crawford finds,
that when an animal is placed in a warm
medium, the colour of the venous blood
approaches nearer to that of the arterial
than when it is placed in a colder medi-
um; and alfo, that it phlogifticates the
air lefs than in the former cafe; fo that
in thefe circumftances refpiration has not
the fame effect that it has in a colder
temperature, in giving the body an ad-
ditional quantity of heat; which is an
excellent provifion in nature, as the heat
is not wanted, but, on the contrary,
would prove inconvenient.

# LECTURE XXXII.

## *Of Light.*

ANOTHER moſt important agent in nature, and one that has a near connexion with heat, is *light*, being emitted by all bodies in a ſtate of ignition, and eſpecially by the ſun, the great ſource of light and of heat to this habitable world.

Whether light conſiſts of particles of matter (which is moſt probable) or be the undulation of a peculiar fluid, filling all ſpace, it is emitted from all luminous bodies in right lines.

Falling upon other bodies, part of the light is *reflected* at an angle equal to that of its incidence, though not by impinging on the reflecting ſurface, but by a power acting at a ſmall diſtance from it.

it. But another part of the light enters the body, and is *refracted* or bent *towards*, or *from*, the perpendicular to the surface of the new medium, if the incidence be oblique to it. In general, rays of light falling obliquely on any medium are bent as if they were attracted by it, when it has a greater density, or contains more of the inflammable principle, than the medium through which it was tranfmitted to it. More of the rays are reflected when they fall upon a body with a fmall degree of obliquity to its furface, and more of them are tranfmitted, or enter the body, when their incidence is nearer to a perpendicular.

The velocity with which light is emitted or reflected is the fame, and fo great that it paffes from the fun to the earth in about eight minutes and twelve feconds.

Rays of light emitted or reflected from a body entering the pupil of the eye, are fo refracted by the humours of

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it, as to be united at the furface of the
retina, and fo make images of the ob-
jects, by means of which they are vi-
fible to us; and the magnifying power
of telefcopes or microfcopes depends
upon contriving, by means of reflections
or refractions, that pencils of rays if-
fuing from every point of any object
fhall firft diverge, and then converge,
as they would have done from a much
larger object, or from one placed much
nearer to the eye.

When a beam of light is bent out of
its courfe by refraction, all the rays of
which it confifts are not equally refracted,
but fome of them more and others
lefs; and the colour which they are dif-
pofed to exhibit is connected invariably
with the degree of their refrangibility;
the red-coloured rays being the leaft,
and the violet the moft refrangible, and
the reft being more or lefs fo in propor-
tion to their nearnefs to thefe, which are
the extremes, in the following order,
violet, indigo, blue, green, yellow,
orange, red.

Thefe

Thefe colours, when feparated as much as poffible, are ftill contiguous; and all the fhades of each colour have likewife their feparate and invariable degrees of refrangibility. When feparated as diftinctly as poffible, they divide the whole fpace between them exactly as a mufical chord is divided in order to found the feveral notes and half notes of an octave.

Thefe differently-coloured rays of light are alfo feparated in paffing through the tranfparent medium of air and water, in confequence of which the fky appears blue and the fea green, thefe rays being returned, while the red ones proceed to a greater diftance. By this means alfo objects at the bottom of the fea appear to divers red, and fo do all objects enlightened by an evening fun.

The mixture of all the differently-coloured rays, in the proportions in which they cover the coloured image above mentioned, makes a *white*, and the abfence of all light is *blacknefs*.

I 4                                          By

By means of the different refrangibility of light, the colours of the rainbow may be explained.

The distance to which the differently-coloured rays are separated from each other is not in proportion to the mean refractive power of the medium, but depends upon the peculiar constitution of the substance by which they are refracted. The *dispersing power* of glass, into the composition of which *lead* enters, is great in proportion to the mean refraction; and it is proportionally little in that glass in which there is much alkaline salt. The construction of *achromatic telescopes* depends upon this principle.

Not only have different rays of light these different properties with respect to bodies, so as to be more or less refracted, or dispersed, by them, but different sides of the same rays seem to have different properties, for they are differently affected on entering a piece of *island crystal*. With the same degree of incidence, part of the pencil of rays, consisting

confiſting of all the colours, proceeds
in one direction, and the reſt in a differ-
ent one; ſo that objects ſeen through a
piece of this ſubſtance appear double.

At the ſurface of all bodies rays of
light are promiſcuouſly reflected, or
tranſmitted.

But if the next ſurface be very near
to it, the rays of one colour chiefly are
reflected, and the reſt tranſmitted, and
theſe places occur alternately for rays of
each of the colours in paſſing from the
thinneſt to the thickeſt parts of the me-
dium; ſo that ſeveral ſeries, or orders,
of colours will be viſible on the ſurface
of the ſame thin tranſparent body. On
this principle coloured rings appear be-
tween a plane and a convex lens, in a
little oil on the ſurface of water, and in
bubbles made with ſoap and water.

When rays of light paſs near to any
body, ſo as to come within the ſphere of
its attraction and repulſion, an *inflection*
takes place; all the kinds of rays being

bent

bent *towards*, or *from*, the body, and thefe powers affecting fome rays more than others, they are by this means alfo feparated from each other, fo that coloured ftreaks appear both within the fhadow, and on the outfide of it, the red rays being inflected at the greateft diftance from the body.

Part of the light which enters bodies is retained within them, and proceeds no farther; but fo loofely in fome kinds of bodies, that a fmall degree of heat is fufficient to expel it again, fo as to make the body vifible in the dark: but the more heat is applied, the fooner is all the light expelled. This is a ftrong argument for the materiality of light. *Bolognian phofphorus* is a fubftance which has this property; but a compofition made by Mr. Canton, of calcined oyfter-fhells and fulphur, in a much greater degree. However, white paper, and moft fubftances, except the metals, are poffeffed of this property in a fmall degree.

Some

Some bodies, especially phosphorus, and animal substances tending to putrefaction, emit light without being sensibly hot.

The *colours* of vegetables, and likewise their *taste* and *smell*, depend upon light. It is also by means of light falling on the leaves and other green parts of plants that they emit dephlogisticated air, which preserves the atmosphere fit for respiration.

It is light that imparts colour to the skins of men, by means of the fluid immediately under them. This is the cause of *tanning*, of the *copper colour* of the North Americans, and the *black* of the Negroes. Light also gives colour to several other substances, especially the solutions of mercury in acids.

# LECTURE XXXIII.

## Of Magnetism.

MAGNETISM is a property peculiar to iron, or some ores of it. The earth itself, owing probably to the iron ores contained in it, has the same property. But though all iron is acted upon by magnetism, *steel* only is capable of having the power communicated to it.

Every magnet has two poles, denominated *north* and *south*, each of which attracts the other, and repels that of the same kind with itself. If a magnet be cut into two parts, between the two poles, it will make two magnets, the parts that were contiguous becoming opposite poles.

Though the poles of a magnet are denominated *north* and *south*, they do

not

not conſtantly, and in all parts of the earth, point due north or ſouth, but in moſt places to the eaſt or weſt of them, and with a conſiderable variation in a courſe of time. Alſo a magnet exactly balanced at its centre will have a declination from an horizontal poſition of about 70 degrees. The former is called the *variation*, and the latter the *dipping* of the magnetic needle.

A ſtraight bar of iron which has been long fixed in a vertical poſition, will become a magnet, the lower end becoming a north pole, and the upper end a ſouth one; for if it be ſuſpended horizontally, the lower end will point towards the north, and the upper end towards the ſouth. Alſo any bar of iron, not magnetical, held in a vertical poſition, will become a temporary magnet, the lower end becoming a north pole, and the upper end a ſouth one; and a few ſtrokes of a hammer will fix the poles for a ſhort time, though the poſition of the ends be changed. Magnetiſm may likewiſe be given to a bar

of

of iron by placing it firmly in the po-
fition of the dipping-needle, and rub-
bing it hard one way with a polifhed
fteel inftrument. Iron will alfo become
magnetical by ignition and quenching
it in water in the pofition of the dip-
ping-needle.

Magnetifm acts, without any diminu-
tion of its force, through any medium;
and iron not magnetical will have that
power while it is in connexion with a
magnet, or rather the power of the
magnet is extended through the iron.

Steel filings gently thrown upon a
magnet, adhere to it in a curious man-
ner; and the filings, acquiring magnet-
ifm by the contact, adhere together, and
form a number of fmall magnets, which
arrange themfelves according to the at-
traction of the poles of the original
magnet. This experiment is made to
the moft advantage upon a piece of
pafteboard, or paper, placed over the
magnet.

Magnetifm

Magnetifm is communicated by the friction, or the near pofition of a magnet to a piece of fteel of a fize lefs than it. For this reafon a combination of magnetical bars will have a greater effect than a fingle one; and in the following manner, beginning without any magnetifm at all, the greateft quantity may be procured. Six bars of fteel may be rendered flightly magnetical by fixing each of them fucceffively to an upright poker, and ftroking it feveral times from the bottom to the top with the lower end of an old pair of tongs. If then four of thefe bars be joined, the magnetifm of the remaining two will be much increafed by a proper method of rubbing with them; and by changing their places, joining the ftrongeft, and acting upon the weakeft, they may all be made as magnetical as they are capable of being.

The ftrength of a natural magnet may be increafed by covering its polar extremities with fteel. This is called the *arming* of the loadftone.

To

To account for the variation of the needle, Dr. Halley ſuppoſed the earth to conſiſt of two parts, an external *ſhell* and an internal *nucleus*, detached, and having a revolution diſtinct from it; and that the action of the poles of the ſhell and of the nucleus would explain all the varieties in the poſition of the needle. But others think that the cauſe of the magnetiſm of the earth is not *within*, but *without* itſelf. One reaſon for this opinion is, that a magnet is liable to be affected by a ſtrong aurora borealis; and another is, that the variation of the needle proceeds in ſuch a manner as ſuppoſes that the motion of the nucleus muſt be quicker than that of the ſhell of the earth; whereas, ſince it is moſt natural to ſuppoſe that motion was communicated to the nucleus by the ſhell, it would be ſlower.

Some idea of the quantity and the progreſs of the variation of the needle may be formed from the following facts. —At the Cape of Good Hope, when it was diſcovered by the Portugueſe, in
1486,

1486, there was no variation, the needle there pointing due north; in 1622 it was about 2 degrees weſtward, in 1675 it was 8° W. in 1700 about 11° W. in 1756 about 18° W. and in 1774 about 21½ W. In London, in 1580, the variation was 11 degrees 15 ſeconds E.; in 1622 it was 6° E. in 1634 it was 4 deg. 5 min. E in 1657 it was nothing at all; in 1672 it was 2 deg. 30 min. W. in 1692 it was 6 deg. W. in 1753 it was about 16 W. and at preſent it is about 21 W.

The longitude may in ſome places be found by the variation of the needle; and Mr. Churchman, of America, having given much attention to the ſubject, comparing the obſervations of others, and many of his own, thinks that he has found a method of determining the longitude to a great degree of certainty, in moſt caſes, by this means.

He ſays there are two magnetic poles of the earth, one to the north and the other to the ſouth, at different diſtances from

from the poles of the earth, and re-
volving in different times; and from the
combined influence of thefe two poles
he deduces rules for the pofition of the
needle in all places of the earth, and at
all times, paft, prefent, or to come.

The north magnetic pole, he fays,
makes a complete revolution in 426
years, 7 days, 9 hours, and the fouth
pole in about 5459 years. In the be-
ginning of the year 1777 the north
magnetic pole was in 76 deg. 4 min.
north latitude; and in longitude from
Greenwich 140 deg. eaft; and the fouth
was in 72 deg. fouth latitude, and 140
deg. eaft from Greenwich.

**LECTURE**

# LECTURE XXXIV.

## Of Electricity.

ELECTRICITY is a property belonging to, or capable of being communicated to, all fubftances whatever; and whereas by fome of them it is tranfmitted with great eafe, and by others with much difficulty, they have been divided into two claffes, and denominated *conductors* or *non-conductors* of electricity. Alfo the latter receiving this power by friction, and other means, are termed *electrics*, and the former *non-electrics*.

Metals of all kinds, and water, are conductors, though in very different degrees; fo alfo is charcoal. All other fubftances, and alfo a perfect vacuum, are non-conductors of electricity. But many of thefe fubftances, when they

are

are made very hot, as glaſs, reſin, baked wood, and perhaps all the reſt on which the experiment can be made in this ſtate, are conductors.

It is the property of all kinds of electrics, when they are rubbed by bodies different from themſelves, to attract light ſubſtances of all kinds, to exhibit an appearance of *light*, attended with a particular *ſound*, on the approach of any conductor; and if the noſtrils are preſented, they are affected with a *ſmell* like that of phoſphorus. This attraction is moſt eaſily explained by ſuppoſing that electricity is produced by a fluid exceedingly elaſtic, or repulſive of itſelf, and attracted by all other ſubſtances.

An electric exhibiting the appearances above mentioned, is ſaid to be *excited*, and ſome of them, particularly the *tourmaline*, are excited by heating and cooling, as well as by friction. It appears, however, that excitation conſiſts in the mere transferring of electricity

city from one fubftance to another, and
that the great fource of electricity is in
the earth. On this account it is necef-
fary to the confiderable excitation of any
electric, that the fubftance againft which
it is rubbed (hence termed *the rubber*)
have a communication with the earth,
by means of conductors: for if the
rubber be *infulated*, that is cut off from
all communication with the earth by
means of electrics, the friction has but
little effect.

When infulated bodies have been at-
tracted by, and brought into con-
tact with, an excited electric, they
begin to be repelled by it, and
alfo to repel one another; nor will they
be attracted again till they have been
brought into contact with fome con-
ductor communicating with the earth;
but after this they will be attracted as at
firft.

If conductors be *infulated*, electric
powers may be communicated to them
by the approach of excited electrics, or
the

the contact of other electrified bodies. They will then attract light bodies, and give sparks, &c. like the excited electrics themselves.

When electricity is strongly communicated to insulated animal bodies, the pulse is quickened, and perspiration increased; and if they receive, or part with, their electricity on a sudden, a painful sensation is felt at the place of communication. But what is more extraordinary, is, that the influence of the brain and nerves upon the muscles seems to be of an electric nature.

This is one of the last and most important of all philosophical discoveries. I shall, therefore, give the result of all the observations that have hitherto been made on the subject, in a *series of propositions*, drawn up by an intelligent friend, who has given much more attention to it than I have done.

1. The nerve of the limb of an animal being laid bare, and surrounded

with a piece of sheet lead, or of tinfoil, if a communication be formed between the nerve thus armed and any of the neighbouring muscles, by means of a piece of zinc, strong contractions will be produced in the limb.

2. If a portion of the nerve which has been laid bare be armed as above, contractions will be produced as powerfully, by forming the communication between the armed and bare part of the nerve, as between the armed part and muscle.

3. A similar effect is produced by arming a nerve and simply touching the armed part of the nerve with the metallic conductor.

4. Contractions will take place if a muscle be armed, and a communication be formed by means of the conductor between it and a neighbouring nerve. The same effect will be produced if the communication be formed between the armed

armed mufcle and another mufcle, which
is contiguous to it.

5. Contractions may be produced in
the limb of an animal by bringing the
pieces of metal into contact with each
other at fome diftance from the limb,
provided the latter make part of a line
of communication between the two me-
tallic conductors.

The experiment which proves this is
made in the following manner. The
amputated limb of an animal being
placed upon a table, let the operator
hold with one hand the principal nerve,
previoufly laid bare, and in the other
let him hold a piece of zinc; let a fmall
plate of lead or filver be then laid upon
the table, at fome diftance from the
limb, and a communication be formed,
by means of water, between the limb
and the part of the table where the me-
tal is lying. If the operator touch the
piece of filver with the zinc, contrac-
tions will be produced in the limb the
moment that the metals come into con-

tact

tact with each other. The fame effect
will be produced if the two pieces of
metal be previously placed in contact,
and the operator touch one of them
with his finger. This fact was difco-
vered by Mr. William Cruikfhank.

6. Contractions can be produced in
the amputated leg of a frog, by putting
it into water, and bringing the two
metals into contact with each other at a
fmall diftance from the limb.

7. The influence which has paffed
through, and excited contractions in,
one limb, may be made to pafs through,
and excite contractions in, another limb.
In performing this experiment it is ne-
ceffary to attend to the following cir-
cumftances: let two amputated limbs of
a frog be taken; let one of them be
laid upon a table, and its foot be folded
in a piece of filver; let a perfon lift up
the nerve of this limb with a filver
probe, and another perfon hold in his
hand a piece of zinc, with which he is
to touch the filver including the foot;

let

let the perfon holding the zinc in one hand catch with the other the nerve of the fecond limb, and he who touches the nerve of the firft limb is to hold in his other hand the foot of the fecond; let the zinc now be applied to the filver including the foot of the firft limb, and contractions will immediately be excited in both limbs.

8. The heart is the only involuntary mufcle in which contractions can be excited by thefe experiments.

9. Contractions are produced more ftrongly, the farther the coating is placed from the origin of the nerve.

10. Animals which were almoft dead have been found to be confiderably revived by exciting this influence.

11. When thefe experiments are repeated upon an animal that has been killed by opium, or by the electric fhock, very flight contractions are produced; and no contractions whatever will take place

place in an animal that has been killed
by corrosive sublimate, or that has been
starved to death.

12. Zinc appears to be the best ex-
citer when applied to gold, silver, mo-
lybdena, steel, or copper.   The latter
metals, however, excite but feeble con-
tractions when applied to each other.
Next to zinc, in contact with these me-
tals, tin and lead, and silver and lead,
appear to be the most powerful exciters.

At least two kinds of fishes, the *tor-
pedo* and the *electrical eel*, have a vo-
luntary power of giving so strong a
shock to the water in which they swim,
as to affect fishes and other animals which
come near them; and by a conducting
communication between different parts
of these fishes, an electric shock may be
given exactly like that of the Leyden
phial, which will be described hereafter;
and if the communication be interrupted,
a flash of electric light will be perceived.

The growth of vegetables is also
quickened by electricity.

<div align="center">K 2          LECTURE</div>

## LECTURE XXXV.

*The same Subject continued.*

No electric can be excited without producing electric appearances in the body with which it is excited, provided that body be insulated ; for this insulated rubber will attract light bodies, give sparks, and make a snapping noise, upon the approach of a conductor, as well as the excited electric.

If an insulated conductor be pointed, or if a pointed conductor, communicating with the earth, be held pretty near it, little or no electric appearance will be exhibited, only a light will appear at each of the points during the act of excitation, and a current of air will be sensible from off them both.

The

The effect of pointed bodies is beſt explained on the ſuppoſition of the electric matter in one body repelling that in another; and conſequently the electricity belonging to a body with a large ſurface making a greater reſiſtance to the entrance of foreign electricity than that belonging to a ſmaller.

Theſe two electricities, viz. that of the excited electric, and that of the rubber, though ſimilar to, are the reverſe of, one another. A body attracted by the one will be repelled by the other, and they will attract, and in all reſpects act upon, one another more ſenſibly than upon other bodies ; ſo that two pieces of glaſs or ſilk poſſeſſed of contrary electricities will cohere firmly together, and require a conſiderable force to ſeparate them.

Theſe two electricities having been firſt diſcovered by producing one of them from glaſs, and the other from amber, ſealing-wax, ſulphur, roſin, &c. firſt obtained the names of *vitreous* and

*refinous*

*refinous* electricity; and it being after-
wards imagined that one of them was a
redundancy, and the other a deficiency,
of a fuppofed electric fluid, the former
has obtained the name of *pofitive*, and
the latter that of *negative*, electricity;
and thefe terms are now principally in
ufe.

Pofitive and negative electricity may
be diftinguifhed from each other by the
manner in which they appear at the
points of bodies. From a pointed body
electrified pofitively, there iffues a ftream
of light, divided into denfer ftreams, at
the extremities; whereas, when the
point is electrified negatively, the light
is more minutely divided, and diffufed
equally. The former of thefe is called
a *brufh*, and the latter a *ftar*.

If a conductor not infulated be brought
within the atmofphere (that is the fphere
of action) of any electrified body, it
acquires the electricity oppofite to that
of the electrified body, and the nearer
it is brought, the ftronger oppofite elec-
tricity

tricity does it acquire, till the one receive a fpark from the other, and then the electricity of both will be difcharged.

The electric fubftance which feparates the two conductors poffeffing thefe two oppofite kinds of electricity, is faid to be *charged*. Plates of glafs are the moft convenient for this purpofe, and the thinner the plate the greater is the charge it is capable of holding. The conductors contiguous to each fide of the glafs are called their *coating*.

Agreeably to the above-mentioned general principle, it is neceffary that one fide of the charged glafs have a communication with the rubber, while the other receives the electricity from the conductor, or with the conductor, while the other receives from the rubber.

It follows alfo, that the two fides of the plate thus charged are always poffeffed of the two oppofite electricities; that fide which communicates with the excited electric having the electricity of the

K 4 electric,

electric, and that which communicates with the rubber, that of the rubber.

There is, confequently, a very eager attraction between thefe two electricities with which the different fides of the plate are charged, and when a proper communication is made by means of conductors, a flafh of electric light, attended with a report (which is greater or lefs in proportion to the quantity of electricity communicated to them, and the goodnefs of the conductors) is perceived between them, and the electricity of both fides is thereby difcharged.

The fubftance of the glafs itfelf in, or upon, which thefe electricities exift, is impervious to electricity, and does not permit them to unite; but if they be very ftrong, and the plate of glafs very thin, they will force a paflage through the glafs. This, however, always breaks the glafs, and renders it incapable of another charge.

The

The flash of light, together with the explosion between the two opposite sides of a charged electric, is generally called the *electric shock*, on account of the disagreeable sensation it gives any animal whose body is made use of to form the communication between them.

The electric shock is always found to perform the circuit from one side of the charged glass to the other by the shortest passage through the best conductors. Common communicated electricity also observes the same rule in its transmission from one body to another.

It has not been found, that the electric shock takes up any sensible space of time in being transmitted to the greatest distances.

The electric shock, as also the common electric spark, displaces the air through which it passes; and if its passage from conductor to conductor be interrupted by non-conductors of a moderate thickness, it will rend and tear them

in

in its paſſage, in ſuch a manner as to ex-
hibit the appearance of a ſudden expan-
ſion of the air about the center of the
ſhock.

If the electric circuit be interrupted,
the electric matter, during the diſcharge,
will paſs to any other body that lies near
its path, and inſtantly return. This may
be called the *lateral exploſion*. The ef-
fect of this lateral exploſion through a
braſs chain, when the quantity of elec-
tricity is very great, will be the diſco-
louring and partial burning of the paper
on which it lies.

If a great quantity of electricity be
accumulated, as in a *battery*, the explo-
ſion will paſs over the ſurfaces of imper-
fect conductors without entering them,
and the effect will be a ſtrong *concuſſion*
of the ſubſtance. Alſo the electric mat-
ter thus accumulated and condenſed will,
by its repulſion, form *concentric circles*,
which will appear by melting the ſurface
of a flat piece of metal on which the
exploſion is received.

If

If an electric shock, or strong spark, be made to pass through, or over, the belly of a muscle, it forces it to contract, as in a convulsion.

If a strong shock be sent through a small animal body, it will often deprive it instantly of life.

When the electric shock is very strong, it will give polarity to magnetic needles, and sometimes it reverses their poles.

Great shocks, by which animals are killed, are said to hasten putrefaction.

Electricity and lightning are in all respects the same thing; since every effect of lightning may be imitated by electricity, and every experiment in electricity may be made with lightning, brought down from the clouds by means of insulated pointed rods of metal.

LECTURE

# LECTURE XXXVI.

*The same Subject continued.*

THREE curious and important instruments which are among the latest improvements in electricity, deserve a particular explanation, and in all of them the effect depends upon the general principles mentioned above, viz. that bodies placed within the influence, or, as it is usually termed, within the atmosphere, of an electrified body, are affected by a contrary electricity, and that these two electricities mutually attract each other. These instruments are the *electrophorus*, the *condenser* of electricity, and the *doubler* of it.

The electrophorus consists of an insulated conducting plate applied to an insulated electric. If the latter have any electricity communicated to it, for example,

ample, the negative, the positive elec-
tricity of the former will be attracted by
it, and consequently the plate will be
capable of receiving electricity from any
body communicating with the earth;
being, in this situation, capable of con-
taining more electricity than its natural
quantity. Consequently, when it is re-
moved from the lower plate, and the
whole of its electricity equally diffused
through it, it will appear to have a re-
dundance, and therefore will give a spark
to any body communicating with the
earth. Being then replaced upon the
electric, and touched by any body com-
municating with the earth, it will be again
affected as before, and give a spark on
being raised; and this process may be
continued at pleasure, the electrophorus
supplying the place of any other electri-
cal machine.

If the conducting plate of the elec-
trophorus be applied to a piece of dry
wood, marble, or any other substance
through which electricity can pass but
very slowly, or if the insulated conduct-
ing

ing plate be covered with a piece of thin silk, which will make some resistance to the passage of electricity, and it be then applied to another plate communicating with the earth; and if, in either of these cases, a body with a large surface possessed of a weak electricity be applied to the conducting plate, the weak electricity not being able to overcome the obstruction presented to it, so as to be communicated to the other plate, will affect it with the contrary electricity, and this reacting on the first plate, will condense its electricity on that part of the plate to which it is contiguous; in consequence of which its capacity of receiving electricity will be increased; so that on the separation of the two plates, that electricity which was before condensed, being equally diffused through the whole plate, will have a greater intensity than it had before, attracting light bodies, or even giving a spark, when the body from which it received its electricity was incapable of it. For though it contained a great quantity of electricity, it was diffused through so large a space that its

<div align="right">intensity</div>

intensity was very small. This instrument is therefore called a *condenser of electricity*.

If an insulated plate of metal possessing the smallest degree of electricity be presented very near to another plate communicating with the earth, it will affect this plate with the opposite electricity; and this being, in the same manner, applied to a third plate, will put it into the same state with the first. If then these two plates be joined, and the first plate be presented to either of them, its own electricity being attracted by that of the plate presented, that of the other will be drawn into it, so that its quantity will be doubled. The same process being repeated, will again double the electricity of this plate, till, from being quite insensible to the most exquisite electrometer,, it will become very conspicuous, or even give sparks. This instrument is therefore called a *doubler of electricity*, of excellent use in ascertaining the quality of atmospherical electricity when ever so small. If this instrument

<div align="right">ment</div>

ment be fo conftructed that thefe three plates can be fucceffively prefented to one another by the revolution of one of them on an axis, it is called the *revolving doubler*; and in this form it is moft convenient for ufe.

T H E   E N D.